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Preface

A being darkly wise and rudely great;

Caught in this isthmus of a middle state

-Alexander Pope, Ode to Man, 1733

The Information Process Architecture (IPA) Project focuses on Communication Systems as a key enabler for the remarkable growth and expansion currently taking place in Information Systems. The Project's inspiration stems from two different considerations that seemed different at first, but which we now consider to be two sides of the same coin.

The first consideration is recognition that contemporary Communication Systems are exhibiting characteristics of Complex Systems, which transcend complicated systems to involve interoperation of independently developed systems, cooperation of user groups that commonly use different operational paradigms and vocabularies, operation with a goal to satisfy rather than optimize, and a state which can never said to be "complete". A means is needed to describe such systems clearly in a way that can be the basis for modeling and simulation, and for facilitating intersections and interfaces that appear as the size and scope of these systems increases.

The second consideration is to explore the aura in semantic space invoked by the term "Cognitive Radio". It is an appealing term in common use for describing solutions to issues arising from current Communication Systems, but the meaning of the term is not precise. A clear understanding of underlying formalities and fundamentals is needed to describe current issues ("as-is state"), and develop means to describe evolving system requirements and application opportunities ("to-be state") in a clear and unambiguous manner.

The common thread between these views is Communication Systems. System entities are components of higher-level constructs, often poorly understood. Systems also contain an internal component structure, so at every level of consideration we can conceptualize higher and lower levels.

But as implied by Pope, we are both capable and constrained in our understanding of these systems, the world in which they serve us, and the impact on our daily lives brought on by the exponential growth of information they enable. Just as our world knowledge falls short of describing the cosmic and subatomic, in every information system there is a complex progression of levels, a structure where our understanding falls between over-arching considerations of society and the minutia of implementation details.

In any consideration of system architecture, there will also be peer-level systems. In defining the scope of our effort we decide whether we ignore them, acknowledge their existence, or define interfaces to interact with them.

Systems also contain an internal component structure, details of which are not needed for system architectural considerations. At every level of consideration we recognize both higher and lower levels; we retain them as environmental factors, but designate them as out of scope. Pope's "isthmus" is our familiar world and the systems we routinely encounter, that middle ground where we start our quest for understanding. To converge to a successful conclusion, the architect needs a clear understanding of system positioning and the ambient structure.

We have an often-observed means of dealing with the imponderable: we ignore it, and limit major intellectual effort to things we aspire to understand. But occasionally we must leave our comfort zone, ponder little-understood areas adjacent to familiar systems functions, and expand our understanding of their impact on us. The reward for that exploration is increased understanding, and expansion of system boundaries within which we are comfortable and can operate effectively.

The IPA exploration of Communications Systems and the Information environment in which they function is organized in two parts. One is Information Process, an exploration of the nature of information, and how our society is changing as the result of Complex Information Systems. The other is Process Architecture, a series of views into Complex Systems to better understand their structure and functionality in order to more effectively control and enhance them.

This document addresses the nature of information systems and the processes involved in their functionality.

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Information Process Architecture (IPA)

1 Introduction

The Wireless Innovation Forum (WINNF) interests include programmable and reconfigurable wireless communications devices, and the information systems they support. Until late 2009, the WINNF placed an emphasis on Software Defined Radios (SDRs) and Cognitive Radio (CR). Following a name and charter change, the SDR Forum became the WINNF with an increased scope to include broader information technology topics and projects including the "Information Process Architecture" (IPA) Project. The IPA Project expands WINNF's resolve to encompass Information Systems architecture and design while maintaining a strong focus on SDRs and CRs. The IPA is further motivated by the blurring of boundaries between computer science, communications engineering, and ever-advancing electronics technology; further enabling our passion for extending the automation of machines and processes used in every facet of our society.

The IPA Project began in 2009 with the realization that it is increasingly difficult for any element of society or industry to function (at least in an economic sense, but frequently also in the technical or political sense) without calling upon sophisticated integrated wireless systems and information systems technologies using complex communications and information systems and networks. This report addresses advances in information systems developed over the past century which resulted in a vast industry most visibly shaped by the rapid acceptance of the Personal Computer, Mobile Telephone, increasingly smaller electronics components, a multitude of wired (including fiber optics) and wireless enabling devices (Microprocessor, DSP, FPGA), and information systems including the modern Internet.

The IPA project recognizes that the wireless industry and Information Systems are experiencing exponential growth, and have motivated substantial interest in research on enhancing communications systems. Conflicts continue over personal and national security information subsystems involving privacy issues, Cyber Warfare, etc., and the sanity (versus economic interests) of the Open Systems Interconnection approaches to Information Systems development is tested. Thus, one is always aware of the drivers of insatiable demand for speed (bandwidth), access, and new mass media opportunities. Subsequently, Information Systems have become the underpinning of our economy and society. As communication system technology advances, many of the processes involved can operate autonomously and no longer require user attention.

Under the IPA effort, our Cognitive Radio Work Group has investigated the evolution of Information Systems, examined their structure, and considered the impact of information technology on our society, economy, and government responses to management of people and resources, wars and geological disasters. We abstracted common concepts from a number of application systems, and generated architectural models of several typical information systems. For this report, IPA is defined by a process inherent to information management – the movement (replication) of data from one geographic location to another.

Our findings show that autonomous operation is a frequently observed property of "Cognitive Radio" (CR). While the term CR has an intuitive appeal, it has lost a precise definition through over-application and a blurring of the evolutionary advances of CR as many kinds of cognitive capabilities are already present in digital systems. Part of the motivation for this work is to understand the nature of what people mean when they talk about "Cognitive Radio."[1]

Within the Wireless Innovation Forum's Cognitive Radio Working Group, varieties of capabilities are associated with CR. Figure 1 is a list of those capabilities in CR, which represents a number of functions, missions, and impacts.

Selected Cognitive Radio Capabilities and Missions

CR Capabilities	CR Missions and Impacts
Dynamic Spectrum Access	*Cognitive (Intelligent) Electronic Warfare*
Cooperative Relaying (Synthetic MIMO)	*Joint Component/Waveform Optimization*
Concurrent Processing	*Role-based (Mission-goal) Reconfiguration*
Cross-network Cooperation/Coexistence	*Dynamic Policy Compliance*
Radio Resource Management	*Power Optimization and Management*
Self Healing Networks	*Spectrum Auctions/Markets*
Interference Suppression (Self, External)	*Dynamic Network (Vendor) Selection*

Figure 1. A partial listing of capabilities the CRWG associated with "cognitive radio"

While the functions associated with these capabilities may lead to very complicated architectures and implementations, they will be critical for handling the enormous volume of information that our society requires to be progressive and "connected". We believe that understanding these systems and how they interact with their environment, with their users, and with each other will be greatly simplified by treating these capabilities and their functions as *autonomous information processes*.

Many researchers in the field admit that Cognitive Radio is an extension of the theory of automation that was the rage in the 1950's to the present day. Dr. Bruce Fette[2] reports the following definition of Cognitive Radio as developed by WINNF and IEEE:

a) *Radio in which communication systems are aware of their environment and internal state, and can make decisions about their radio operating behavior based on that information and predefined objectives. The environmental information may or may not include location information related to communications systems.*

[1] Dr. Joe Mitola, originator of the term "Cognitive Radio", SDR Forum, and IEEE P-1900.1 have all provided definitions for the term, with a common thread of radios that are "aware" of their surroundings and react to them to achieve their goals.
[2] Bruce Fette, Editor, Cognitive Radio Technology, Academic Press, 2009, Chapter 1, History and Background of Cognitive Radio Technology.

b) *Cognitive Radio (as defined in a) that uses SDR, adaptive radio, and other technologies to automatically adjust the behavior or operations to achieve desired objectives.*

Some researchers refer to CR's as *Intelligent Machines*, *Thinking Machines*, and/or *Learning Machines*. Moreover, certainly the theories in the field of Cybernetics and its benefits apply to CRs. A generally accepted attribute of CR is that CRs are a class of machines that are adaptive to the environment and incorporate the so-called "*Artificial Intelligence*" research from the 1970 onwards. We propose that CR theory should not be considered as a technology. Rather, it is a paradigm that applies adaptive machine learning processes useful in computer-communication systems engineering to enhance the systems' environmental awareness, utility, and functionality.

We also propose a framework within which cognitive (learning) functionality is found in autonomous processes that achieve core system objectives to enhance performance and utility of the systems. The IPA is thus a means by which we can understand and accurately represent the functions of CR in the architecture and design of systems in a coherent and consistent way. It is hoped that this endeavor with these high-level goals and attributes will be of significant value to our society.

With a view of how information technology has evolved, we proceed into the document in the following order.

- Chapter 2 provides further background and reviews the impact information systems and other innovations have had on society.
- Chapter 3 introduces a very high-level framework where information system characteristics and environment are described.
- Chapter 4 presents a discussion of the major types of information system elements, and differentiates between User Controlled and Autonomous Processes.
- Chapter 5 describes the flow of data and information through the communication cycle of an information processing system.
- Chapter 6 overviews work products that should be dealt with in detail in future work for this project.

In a general sense, the thrust of the IPA project will then help us achieve an understanding of the structure of Information Systems and their role in their environment. It can be observed that these systems have consequences (intended and unintended) which alter their environment. Investigation of the operative mechanisms for those alterations is left for a future authors and endeavors.

With the remarkable progress now occurring in radio technology, nano-technology, and Information Systems, their newly developed architectures will likely produce exciting advances in IPA for the next generation. Continued exponential improvement in the underlying technology is expected to hold for the long-term future, which implies that far more convergence of communications and information systems is on the horizon. These are exciting times with many opportunities to see the promise of IPA fulfilled.

2 Information and Technology Evolution

Technology in the past two hundred years has exhibited two distinct forms of change: evolutionary and disruptive.[3] Evolutionary changes are seen as a series of improvements to an existing capability, while a disruptive change introduces different capabilities that lead to a new way of doing things.

A progression can often be observed: a new technology becomes prevalent, and, as improvements are made and it matures, a feeling of status quo prevails. Then a new technology arrives, often provided by new participants in the market, impacting both users and providers of the technology being replaced. Disruptive change subjects our economic and societal system to forces that can bring about major changes.

We suggest that the current information age is beginning to be supplanted by an age of intelligent systems as we incorporate autonomous, self-directing processes into our information systems. Consideration of past progressions can be informative as we consider implications of future technology developments in information processing. By understanding past transitions we can gain perspective as to how innovation has evolved in the past and obtain insight into how this new transition may play out.

2.1 Technology Shifts

It is the intent of this section to look at four long-term evolutions of technology over time in our society and economy, and to present one possible glimpse of the future. This is to better understand the consequences of fundamental shifts in the technology underlying current communication and energy management systems. Progress over the past 200 years provides a context for understanding how to architect the future in the most beneficial way.

We propose five major epochs:

- Steam Power Before 1850
- Electricity 1850 -1920
- Electronic Communication 1920 - 1950
- Information 1950 - 2000
- Intelligence After 2000

Figure 2 shows the five epochs and timing of a few illustrative innovations. The formal boundaries presented between epochs are quite arbitrary as there is considerable overlap in the timing of the emergence of important new inventions.

[3] See Clayton Christiansen in Appendix A.

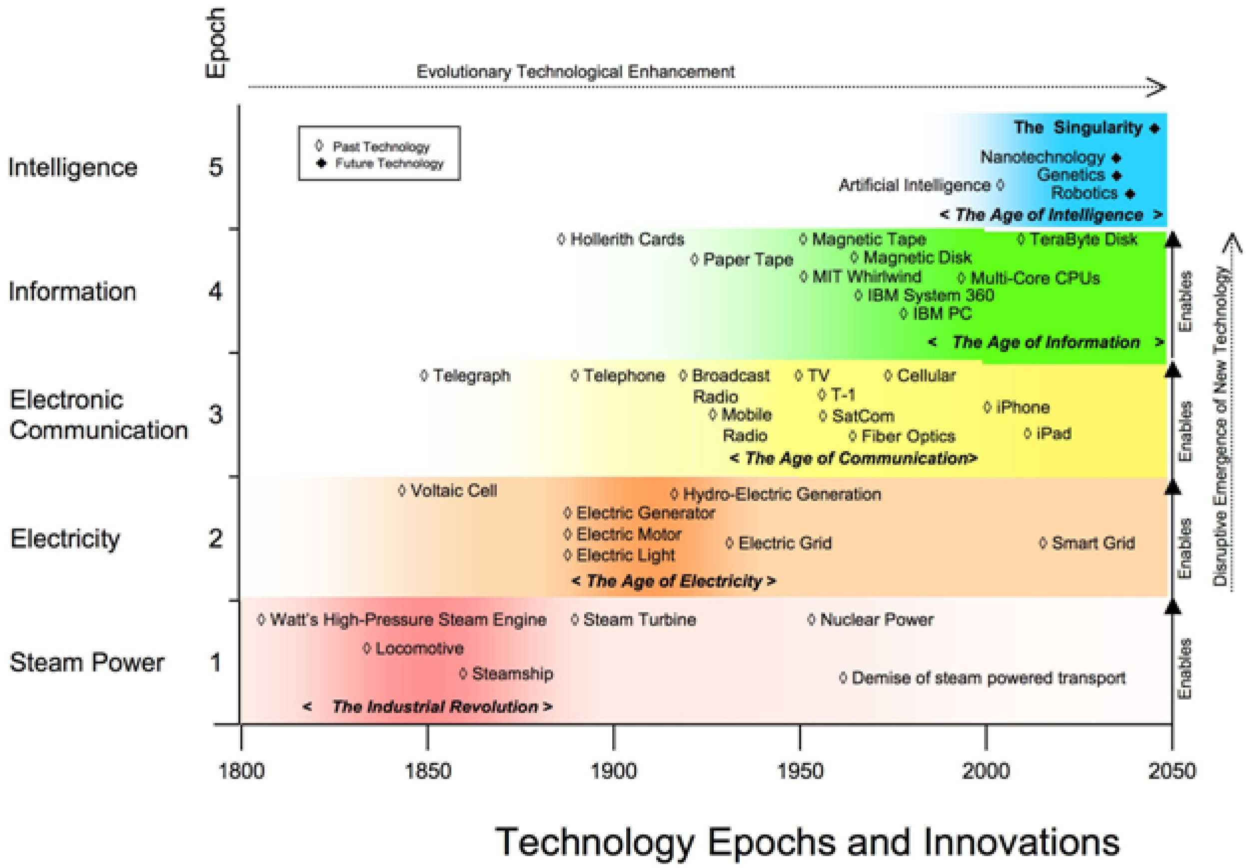

Figure 2.Technology Epochs

Consideration of such a timeline of technology development, and observation of economic and societal system evolution during these time periods, provides insight into the evolution of current state of affairs over time, and a perspective with which to explore likely future directions.

2.2 Steam Power

For most of known history, human and animal brawn were the primary sources of mechanical power. Waterpower found some use in limited locations where local geographic conditions permitted. Wind was harnessed for grinding grain, pumping water, and to propel boats. But for the most part, when fields were plowed or produce taken to market or when ideas were implemented, muscles provided the needed power.

The first half of the nineteenth century saw the development of steam engine technology. Water was boiled to produce steam under pressure; releasing that pressure through an engine produced torque that could power tools, drive the wheels of a steam locomotive running on a steel track, or realize many different machines including those previously implemented with water, wind, or muscle power.

Communications were impacted because letters, newspapers, and books could move faster and for longer than that horse or man. Society changed dramatically as the industrial revolution attracted workers from rural settings to work in factories in urban settings. Productive power was no longer limited by geography as a steam engine could be built anywhere. The economy benefitted from the availability of mass-produced goods and wages to pay for them. Over time, a significant proportion of the population in developed countries experienced elevation to middle class economic status.

The principles of the steam engine led to another disruptive change precipitated by the introduction of internal combustion engines. Powered by liquid hydrocarbons, these lightweight devices enabled mass-market (and safer) automobiles and aircraft, devices that no longer had to deal with the weight associated with water tanks and steam boilers. The resulting mobility meant that workers had much greater flexibility in living arrangements (but still limited by the commute), which led to suburban migration, rapid long-distance travel - airliners offered a new dimension in travel.- and much greater international commerce. As combustion engines were small enough to allow for economical vehicles for individuals, transportation became more autonomous so that mass transit, such as trolley cars and passenger trains, was no longer the dominant mode of transportation for many.

2.3 Electricity

Electric generators and motors became practical around 1890, and with a grid of electric lines, were able to carry current away from the power source to multiple points where mechanical power, light, and heat were needed. No longer did the power source need to be co-located with its load as vast power distribution networks were built to connect power plants with electric devices. After much debate, alternating current emerged as preferable to direct current as it permitted use of transformers to increase voltage and reduce current for distribution and long distance transmission with less transmission loss.

Freed from needing to include a power source within the device, many new inventions were enabled as electricity was harnessed. Home lighting changed the family way of life as the entire house could be lit rather than having family members grouped around a candle. Fractional-horsepower electric motors enabled many home appliances. Automobile design benefitted from electric starters and headlights for night driving.

2.4 Electric Communication

Building on the availability of electricity, in about 1850 the telegraph was invented, introducing an era of electric communications. One operator worked a key that opened and closed a circuit in accordance with a specific code. At a remote location, the receiving operator listened to a sounder, and wrote down the message letter by letter. For the first time, two people could obtain communication beyond the line of sight at the speed of light. An important early application was use by railroads to control emerging transcontinental trains (an outgrowth of the steam power age).

In 1878 Alexander Graham Bell was issued a patent for the telephone, narrowly (by hours) beating out Elisha Gray, who had a similar set of inventions. Now skilled telegraph operators were not needed; human voice was reproduced at a distance. People could talk with each other without being at the same place and without human, animal, or steam power to convey the message.

In assigning the beginning of the era of communications to 1920, we invoke the emergence of wireless broadcasting, when Radio Station KDKA, in Pittsburgh, PA went on the air. In a short period of time listeners were reported from around the world. For the first time large populations could get breaking news in real time.

In a short period of time radios were installed in automobiles, first receive only, and then two way. Police Officers no longer had to stop to use a telephone call box to communicate with dispatch. Aircraft radios were close behind.

Even as later ages emerge, electric communication continued to evolve. With the advent of computers for use in business data processing in the 1950s, the need to move data became apparent. Modems provided an opportunity to connect computers over the switched telephone network, followed by direct connections to the T1 lines that became available as AT&T converted to digital switching with SS7.

These technologies supported creation of vast amounts of information, and enabled the networks needed to distribute it. By the end of the twentieth century the world was strung with optical fiber, much of it dark to provide future capacity.

The “Last Mile” gap to individual homes remains a problem, and universal availability of wireless broadband may emerge as the definitive solution. The Internet protocols, TCP/IP, have emerged as the basis for universal connectivity, paving the way for the epoch of Information.

2.5 Information

Around 1889 data processing emerged using electric circuits. Punched cards were developed to automate compilation of the 1890 census data, which evolved later as “IBM Cards”. Containing twelve possible hole positions per column, they permitted automated manipulation of eighty-character records. Electro-mechanical sorters permitted them to be placed in different sequences, and paper reports generated from relay-based tabulating machines.

However, we mark the disruptive tipping point into the Information era as 1950, with development of the Whirlwind computer at MIT, a computing machine based on vacuum tubes. It featured binary digital information storage, with a major innovation in computer control as machine instructions were stored in the same memory as data, and could be themselves manipulated.

As the concepts of computation were developing, along with languages such as FORTRAN and COBOL, computer hardware took a quantum (literally) leap with invention of transistors and the integrated circuit.

Initially computers were called "mainframes", installed by large corporations, and occupying special rooms, often with display windows. Most software applications were laboriously hand-crafted, with individual corporate idiosyncrasies hard-coded in. In time, input and application information access were provided with large cathode ray tube terminals costing several thousands of dollars.

In 1981 another disruptive change was initiated from an unlikely source: IBM developed a small, inexpensive computer product. The IBM 5051 Personal Computer (PC) used an early Intel microprocessor chip and sold for about $3,000. Within fifteen years every desk and most homes had a networked PC that built on the combined outputs of the electrical, electrical communication, and information epochs. Consumers and professionals typed their own documents, presentations, and spread sheets. Email replaced ditto memos, and secretaries evolved into administrative assistants, who took no dictation and typed only their own documents.

In a related development, a Defense Advanced Research Project Agency (DARPA) network technology spread explosively, connecting a billion of those desktop computers worldwide. (It is notable that an estimated 80+% of their machine cycles go unused.) Every home has one, revolutionizing shopping, information retrieval, advertising, banking, gaming, and many other aspects of everyday life. Newspapers and magazines have struggled or disappeared, and many people work from home. It is hard to exaggerate the extent to which this information revolution has changed every aspect of our economy and everyday life.

2.6 The Future: Intelligence

Ray Kurzweil[4] estimates that by 2030 computer intelligence will have reached a level equivalent to human intelligence, and will be capable of designing their own succeeding generations. The recursion of machine designing and building successively more sophisticated machine with a design cycle that far exceeds human capabilities is predicted to mark a marked transition (the "Singularity") where machine-designed and built systems will rapidly go far beyond the capabilities of human engineered systems.

Building on that assertion, there are some system architecture capabilities that the IPA Project suggests we can look forward to as processing cost-per-machine cycle approaches zero and digital storage becomes infinite.

- Every individual is uniquely identified at all times, and their geolocation is known. Identity theft is impossible. All transactions, including schooling, purchases, earnings, entertainment, food preferences, medical records, and others, are recorded. Privacy protection is provided, but crime rates are negligible because law enforcement can access relevant data.
- Everybody is always connected through personal and desktop terminals, the Internet, and commercial wireless networks.

[4] See Ray Kurzweil in Appendix A

- Everything in the world is identified. During manufacture or processing an identity is provided and tracked through commercial distribution channels. Ownership of everything and its current location is well-defined.
- Change of location (movement) is managed to optimize traffic flow and avoid traffic congestion.
- Optimization is performed on a very large scale (e.g., nationwide energy grid).
- Precisely the right information is always available, synthesized from all relevant data, and put into context (Information Resonance).

It is hard for us to realize what life was like two hundred years ago. Society was rural, based on crafts, and most people lived their entire lives in a very small area. Now we are urban, mobile, well-traveled and interconnected. Even the social contacts of the younger generations are in large part conducted online.

2.7 Disruptive Technology Impact

As we have noted, innovation comes in two forms, evolutionary and disruptive.[5] Evolutionary enhancement of existing technology often finds ready acceptance because familiar, existing functionality is extended, faster, or cheaper. Acceptance of disruptive technology is often more difficult, as it involves fundamental changes in the way systems operate, and frequently results in substantial impact on in the system's environment. Kuhn has popularized the related term "paradigm shift". He also asserts that some individuals accept such changes reluctantly, and others never do adopt certain of these disruptions, retiring from the field instead.[6]

The difficulty and rate of adoption of disruptive innovations are influenced by certain characteristics. As defined by Rogers they are: Relative Advantage, Compatibility, Complexity, Trialability, and Observability (or Visibility).[7] Understanding the history of innovation and its impact on civilization in these five epochs can help us prepare for future changes by designing information systems that can accommodate our changes thereby reduce our discomfort with disruptive technologies.

The shift to the age of information was disruptive, not an evolutionary enhancement of our ability to communicate data. For example, entire new ways of doing business emerged as credit card transaction systems (which couple communications with information about users) became widespread. Information System technology is well in hand; we are at the inflection point that will result in effective Knowledge Systems.

The IPA project is considering a number of aspects of complex systems, both technological and non-technological, with the intent of making system architecture practitioners aware of the scope of the outreach efforts needed for the success of their ventures. By providing products to help them make clear how proposed systems will benefit stakeholders, and by sensitizing them to the

[5] Section 2, op. cit.
[6] See Thomas S. Kuhn, Appendix A
[7] See Everett M. Rogers, Appendix A

need for system implementers to garner support, there is an opportunity to improve the complicated process of system implementation.

3 Information System Framework

Section 3 presents an overview of the attributes of an Information System. We start by introducing the Information System Framework, which allows us to understand how information systems and the world interact, each influencing the future shape of the other. In subsequent sections we consider information system modeling to illustrate how incorporating autonomous functionality impacts information systems.

This generic view is intended to be at a level high enough in a hierarchy of system structure levels to depict the environment within which the system functions, but not so high as to be overly abstract. The degree of abstraction is important because it serves to facilitate communication and understanding of system concepts across user domains. To technically involved system developers and operators it is a very general representation. But to non-technical decision makers it seems quite detailed, although not overwhelming. Thus it serves as a bridge across which both communities can communicate effectively, and coordinate decision-making, leading to a more effective implementation.

3.1 The Information System Framework and Its Components

Table 1 and the following sections describe the six components of the IPA Information System Framework

Table 1: Information System Framework Components

Framework Component	Description
Purpose	Application area, motivation, goals, requirements, and preconditions under which the system operates
Scope	For the target system, define the higher-level overarching system of which it is a component, its own lower-level component systems, and relationship to peer systems
Technology	Underlying technology that enables the System and is used by it, level of technology maturity, evolutionary or disruptive
Economics	Business case for the System, Revenues, Cost structure, who pays, who profits
Politics	Regulatory considerations, public funding, benefits, legislative support, popular support, volatility of support
Structure	Identification of higher-level System, interfaces to and interaction with sibling Systems, process structure, precursor to System design

3.2 Purpose

Information Systems are constructed to support execution of plans developed by an organization to achieve its goals. Activities included in the plans lead to requirements for information collection and channels for delivery of information, transactions, and directives. The Purpose component is where these items are explained.

A number of preconditions exist in the environment in which any system is used. In most cases these items are implicit, accepted without detailed consideration, debate, or even recognition. If any of these pre-existing conditions are to be made explicit they will be considered part of model Purpose.

3.3 Scope

In general, Information Systems are open, meaning that they interact with their environment. They do, however, have recognizable boundaries, and the Scope element of the framework is where those edges are recognized and described.

System enhancements often include an increase in Scope, which, in turn, may bring the system in contact with another system that was previously completely independent. When such systems intersect, we describe their union as a “complex system”. This part of the framework is where consideration is given to system boundary conditions, and where interfaces with the environment are identified.

Information Systems exist on a series of levels, where lower levels indicate increased detail and representation of the internal structure of higher-level systems. For the target system, Scope also includes definition of the higher-level overarching system of which it is a component, its own lower-level component systems, and its relationship to peer systems

3.4 Technology

This component deals with system attributes that are influenced by the underlying scientific principles applied to it. System design should facilitate migration to new and better system components as developments in semiconductor and other technologies, such as beam-forming, modulation techniques, and network interfaces, can be brought to bear to improve system performance and effectiveness.

Data capacity is a function of available bandwidth and quality of the link (signal to noise ratio). Efficient use of spectrum, a scarce resource, requires that spectrum occupancy and signal waveform characteristics be engineered to meet specific capacity requirements. As hardware performance improves, sampling rates can be increased, resulting in more faithful signal representation, but also increasing need for communications bandwidth, source data filtering techniques, and storage.

3.5 Economics

In a resource-constrained world, society necessarily prioritizes where it places its resources. This also holds true for information systems (IS). The economics aspect captures the tradeoffs (i.e., costs vs. revenues) that impact IS. Often, it is the Economics attribute that dominates the decision to deploy an IS. Further, as the Economics attribute captures much of the interaction of an information system with society, it is an important indicator of the impact an IS has on society

Any information system proposal should recognize two categories of cost: the first is implementation cost, also known as first cost or capital expenditure. The second is recurring cost or operating cost. As there are often trade-offs between these two categories, their sum over a period of time - life cycle cost - is a preferable indicator to either cost category alone. If the system generates revenue, then development of sources of revenue, determining operating margin (revenue minus operating cost) and predicting those values over time, is critical.

For systems which do not generate revenue, such as military or public safety, there is no revenue in the Economic view, but life cycle cost is still an important consideration. Reductions in life-cycle cost free up funds to provide additional functionality, or to be applied to alternate needs, thereby improving the ratio of cost to benefits.

Internet-based ISs have a number of characteristics that differentiate them from non-electronic and many other electronic means of delivering information. One is that the incremental cost, that is the cost of handling one additional transaction in a large operational system, is infinitesimal. Unlike information embodied in a physical medium, digital information is copied, rather than moved. The result is that digital files can be replicated endlessly without loss of quality at very low cost. Using an incremental cost approach can result in a large number of “free” services offered and leads to a large audience holding the expectation that payment for service is to be avoided. For the print media, in particular, this situation has resulted in loss of revenue needed to cover the real cost of providing content.

Some information services, such as Amazon’s Kindle and Apple’s iTunes store, have been successful with business models that require payment for content. A marketing strategy involving a large number of transactions sold at very low prices has proven to be an economically viable strategy for them. The dramatic growth of cellular service to a trillion dollar business in three decades is also evidence that consumers will pay for services that they value highly.

Development projects are labor intensive and costly. Hardware expense for large systems is substantial. So it is important to establish a stable cash flow as payment for services. For non-revenue systems, long term budgetary support is necessary (and may have political implications as well). Even when a good initial economic posture is developed, over time emerging technologies may offer similar capability at lower cost, resulting in decreasing revenue for older for-profit systems.

Another consideration is the expectations of system users. Very high usage data volumes result from easy access to information processing, so even a small per-transaction charge can be economically important. But once an expectation of free service is in place, it is very difficult to introduce even small fees.

3.6 Politics

Economic and technological considerations represent much of the constraint structure imposed on an information system. We will use the term “politics” to mean any other impact on such a system such as those imposed by law, regulation, public sentiment, or executive policy.

Conditions under which emission of radio frequency energy is permitted are a significant consideration. Outcomes such as licensed versus unlicensed operation, access to spectrum, and interference policy have fundamental impacts on system design and operation. Policy also has an economic impact when spectrum license rights are assigned by auction, when fees for service are taxed, and when politics are used to demand certain operating rules, such as Net Neutrality. In systems involving consumer financial transactions, legal restrictions may be imposed to restrict abusive practices.

A number of techniques are available for cryptographic protection of information. Higher levels of security have higher cost, added complexity, and slower transit time, but with the benefit felt typically in the political realm.

Another consideration is political risk, particularly for government employees. If adoption of a new paradigm leads to undesirable circumstances, the potential for detrimental consequences can be daunting. Criticism of inactivity, delay, and extended study may be seen as far less of a danger than adopting a risky course of action. The extended delay in providing effective air traffic control facilities is a classic example of aversion to perceived risk.

3.7 Structure

Structure is an overview of how the system is put together, the system architecture, design, and interfaces. At the level of the Framework, our view of the Structure is general, an overview. It will often be depicted by a simple picture or diagram. Below this level are lower layers of increasing detail, with implementation at a much lower level.

An important objective of the IPA is a means of representing the structure of systems in a common notation that transcends arbitrary differences brought about by inconsistent vocabulary, legacy practices, and system engineering practices. In the Sections that follow we will describe means of portraying process interaction at more detailed levels, and present a notation that can be applied in a common fashion to diverse systems, and used to facilitate system interaction. Later work can consider how this can be captured in a unifying set of architectural views.

3.8 The Role of Hardware

Having described the Framework, we must consider hardware, and define its role in the system. The focus of our approach in IPA is processes. In information systems, a process is often implemented as software, but a hardware implementation may be used when performance is an issue and a business case supports the decision. Even when a process is implemented in software, it must have a processor on which to execute. Hardware is also used in Information Process Systems to store data when it is not being processed and to move data from one place to another. So the hardware environment is an important consideration.

In the past, engineers implementing systems have often focused on the hardware with which the system is implemented. But with the increasing importance of information systems, architecture, structure, and software are often more important than the hardware on which it is implemented. A Google query, for example, will execute simultaneously on a number of processors with access to arrays of data storage devices; both processors and disks may be located anywhere in the world and reached in microseconds through the Internet. The information returned from an inquiry comes back to be presented to us in a matter of seconds; typical users do not care where in the world the information came from.

Further, those disks that returned the information all look alike to the human eye, but the vast array of microscopic magnetic domains on a given disk may be the data from the 2000 U.S. Census, a few hundred thousand books, or all of the ten million articles in Wikipedia. The information storage devices carry is only of value or even interest in the context of the Information Processing Systems they support.

There are a many kinds of hardware in the system, essential to its functions, but with few implications for the Information Process Architecture. Hardware devices gather information for the system, display it, generate hard copy, and emit sound – performing the physical functions by which an Information System operates and interacts with the world. Thus while hardware is important, the performance constraints hardware imposes are diminishing as there are many ways to implement the same processes and it is not the hardware itself that carries value (economic, political, and frequently technical) within the context of the Information System Framework, so it is appropriate to focus on functions and processes without detailed concern for their means of implementation.

The Information System Framework is thus hardware agnostic; dealing with information processing without consideration of the mechanisms by which information is transformed, moved, or stored. This is a new paradigm for those engineers who have spent much of their careers developing innovative new hardware products with the latest technologies, but is entirely consistent with Software Defined Radio which exhibits a similar relationship with hardware. So hardware is everywhere and nowhere in this Framework. The system cannot run without its hardware and the hardware consumes real electrical power that has to be paid for. This model and the entire IPA project operate with a presumption that we have adequate and effective hardware. But the crux of our effort is understanding information and the impact it has on society, government, economics, entertainment, how the information systems are implemented as processes, how they grow and interact, and their impact on a number of other aspects of our lives.

4 Information System Structure

This section describes a level at which Information System elements are visible. Figure 3 illustrates a general model of an Information System consisting of three functions:

- Application-specific Processing
- Data Storage and Management
- Data communication

These functions are supported by an element called system services. This picture categorizes types of functionality not specific process interconnection or interaction. Data Communication is data in motion, Application Processing is data in use, and Data Storage is information available for use. Current Data is that to which processing is being applied. Historical Data is kept in storage for future use.

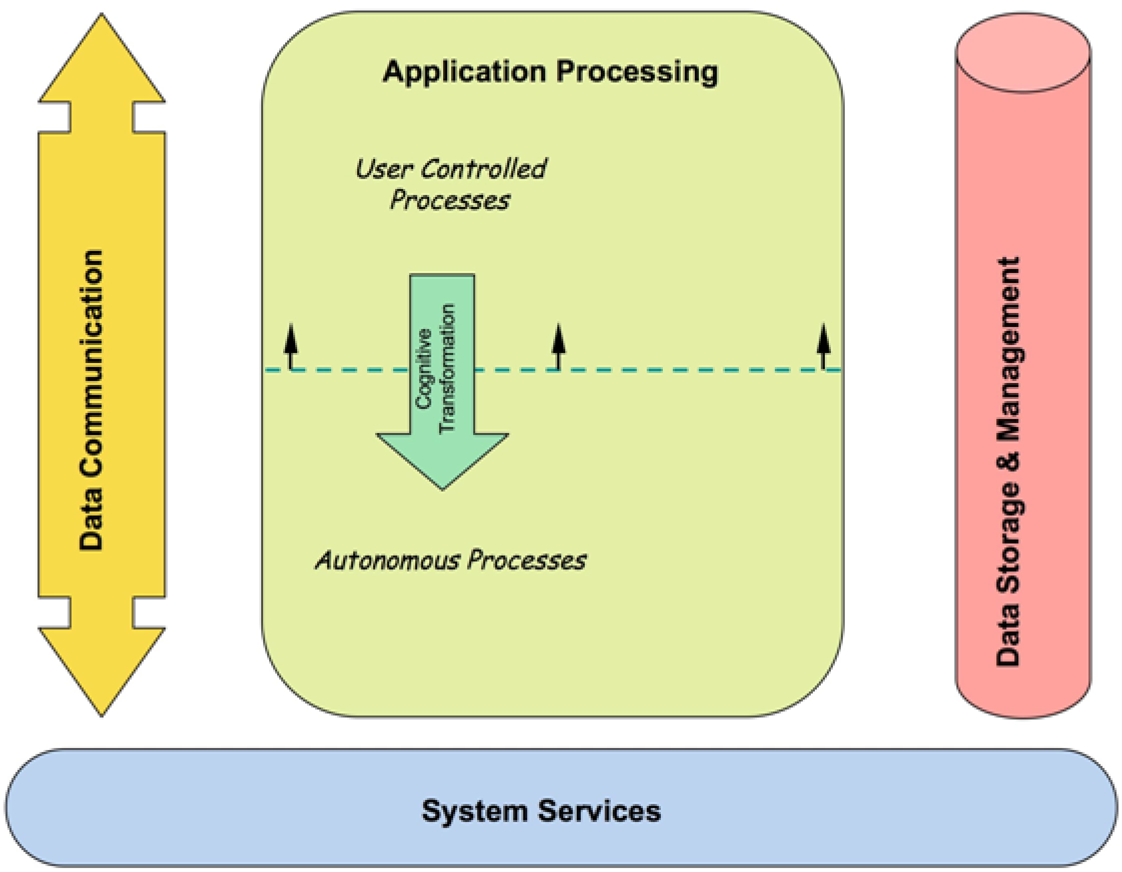

Figure 3. Information Process System Structure

4.1 System Services

This element consists of functions and processes provided by operating systems and other system functions to support system operation. It is an abstract representation of underlying hardware and low-level support services. A key attribute of these services is that they are application independent, providing functionality that any application can call on.

4.2 Data Storage and Management

Data Management is a primary aspect of an information processing system. Data is initiated, replicated, processed, and delivered as information to fulfill the goals of the system architecture. A key consideration is that, unlike written records, data transfer implies data replication so that data is not inherently lost at the source of a data transfer; its constituent bit configurations are replicated at the destination.

Data is stored in different formats along the way, communicated to multiple locations, processed in a number of different contexts, and finally ends in archival data warehouses. Data storage is concerned with accurately storing the information, safeguarding it, retrieving it when needed, and freeing space when the data is no longer needed (though with increasing storage, this is becoming less important). The key is to access the information that you need when you need it

Widespread adoption of computers in all facets of society, coupled with dramatic reduction in the cost per Gigabyte of storage, has led to an overload condition sometimes called "The Data Deluge."[8] As generation and accumulation of digital information is growing at an exponential rate, coping with the volume as a user is increasingly becoming a problem. There is great value to being able to sift the sea of data to provide actionable information. Search engines and data mining are examples of processes that perform this increasingly vital function.

Although not commonly explicitly stated in the Enterprise Balance Sheet, data and the information derived from it are widely recognized as enterprise assets.[9]

Of particular interest in IPA are the issues that arise in Complex Systems when two independently developed systems need to exchange data over a direct interface. If the architecture of both systems is clearly documented, specifications for data definitions and formats can be used to confirm that information can be transferred from one to the other, and safely used. In some cases special measures will be needed to insure accuracy. An example of the problem is confirming that Social Security or personal identity numbers found in independent systems really pertain to the same physical human being. Further the data deluge often implies that context must be transferred along with the data to allow users of both systems to properly apply the information.

[8] See Special Report "Data, data everywhere", The Economist, February 27, 2010, available at http://www.economist.com/specialreports
[9] The DAMA Guide to the Data Management Body of Knowledge, Data Management Assoc. 2009, pg. 1 http://www.dama.org

4.3 Data Communication

The fundamental commonality of digital information systems and their components is replication of strings of binary digits, or bits. Bits can exist in a large number of physical devices; the only requirement is some physical element with two states that can be designated as a one or a zero. The function of digital communication systems is to replicate the binary configuration of some bit string in another location. Merely transferring data is insufficient; the context in which those bits can be interpreted to transform them from data into information is a fundamental part of Information System design.

Wireless systems are of particular interest to Forum members because they provide untethered data communication links, and enable communications for people and vehicles in motion. But IPA will consider both wired and wireless bit transfer; each provides a bit stream for transmission from an Originator to a remote Recipient. Specific protocols being used to convey the data (e.g., P25, LTE, WiFi, WNW) are not a focus of the IPA but should be viewed as being subsumed in the data communication process.

4.4 Application Processing

This element uses and transforms information by combining data from multiple sources, computing to form new data, and delivering information in a form that advances system goals. Details of processing and process structure are application dependent and define the basic functionality of the system.

This structure makes a distinction between two classes of processes: User-Controlled and Autonomous. The distinction may not always be clear-cut, but making it is helpful in observing system behavior and to understand the emerging Intelligence epoch.

User-Controlled processes are directly commanded by the System user. To enable user control, these processes are deterministic so that given a set of inputs the result is known and the user can make meaningful decisions about the operation of the System. The logic to implement these processes may be quite complex and it can be built into software logic during programming, but execution of the software remains under control of the user.

As mentioned in the Introduction, Autonomous Processes are those that operate independently of the system user. They monitor their environment, and, when triggered, initiate action to improve the system's goal-oriented behavior. Because these autonomous processes are maintaining their own states and making choices for their own goals, from the perspective of the user, the system may appear less deterministic because the input-output relationship is not fixed, thereby obscuring the meaning and operation of aspects of the System. The preceding difference in apparent determinism for user-controlled and autonomous controlled processes captures a key feature for the shift into the Intelligence epoch – for a user controlled process, it is vital that the information used and the result be understandable by the user, but for an autonomous process, only the autonomous process has to understand the meaning of the information and the input-output relationships. Presumably the autonomous processes still serve the objectives of the user, but the user does not have to understand the Information System's autonomous processes to use the Information System.

In Figure 3, a dashed line separates the two types of processes. As indicated, system evolution often involves enhancing User-Controlled Process to make them autonomous, a conversion we have called "Cognitive Transformation"; processes what were previously invoked by the user take action when conditions indicate they should. As those enhancements are made, the dividing line moves up; fewer processes are User-Controlled and more are Autonomous.

Many of the definitions of cognitive functionality invoke terms from human psychology; equipment that is "aware", "perceives", has "knowledge", and "decides." Sometimes an ability to "learn" is held to be essential to use of the "cognitive" designation.

We recognize a phenomenon called "submergence", whereby cognitive functionality is capability yet to be implemented. Once it is implemented and put into operational service, it is "just software", becomes part of the product system, and loses much of its cachet.

Trunked land mobile radio is an example of submergence; at one time the idea that a group of *n* channels could support more than *n* talk groups by assigning working channels dynamically and directing radios of all members of a talk group to the designated channel might have been considered "cognitive." Now, however, it is commonly accepted that this is "just the way trunked LMRs work".

IPA will not make significant effort to clearly define cognitive functionality and will accept it as a working paradigm rather than a technology. Our goal is to provide tools to facilitate architecture of complex systems and to prepare the reader for the Intelligence epoch. We will deal with cognitive capability in terms of the functionality it enables, as presented in Figure 1. It seems clear, however, that to the extent cognitive functionality in general and cognitive radio in particular are considered, the system locus of that functionality must be in the autonomous processes of the application processing element of the system.

A note about database and communication systems is in order. As described in the introduction, all systems are hierarchical. The Information Process Architecture structure has major elements designated with that functionality, as shown in Figure 3. Those elements are themselves systems. So when we are considering a system that might be designated "Cognitive Radio", it will have Application Processing, Data Storage, and Communication elements. Its Data Communication element will be that lower-level functionality that is used to execute data transfer. Its cognitive functionality will be found in autonomous processes of its Application Processing element, wherever they are executing. As a whole, it will be the Communications Element of a higher-level system.

5 Information System and Context

Philosophers throughout the centuries have pondered about the true nature of information and knowledge, and even existence. Descartes famously said "I think, therefore I am" (In Latin:

"Cogito, ergo sum"),[10] relating existence to the human capability for abstract reasoning. Knowledge is product of intellectual activity in response to data resulting from interaction with our environment. It is the result of information attended, understood, and remembered. Wisdom is knowledge applied with insight to current situations.[11]

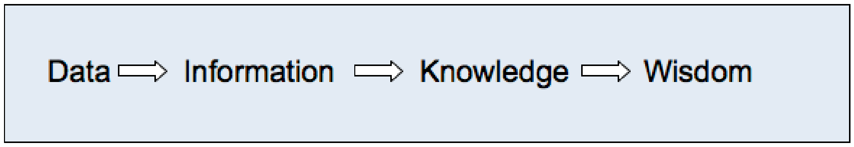

Figure 4. DIKW Conceptual Information Hierarchy

As represented in Figure 4, some observers designate this hierarchy as DIKW [12], with machine processing most effective on the left, and activity increasingly characteristic of the human mind moving to the right.

Data is a set of symbols providing a representation of facts, as measured, observed, or implies by some sensor or observer. It is the fundamental element of Information Processing Systems, where it is the basic element of an information processing cycle during which it is captured, processed, communicated, and received.

Information is data taken in context, enhanced by past experience and understanding of response to a set of hypothetical who, what, when, where, and why questions.

Knowledge is Information ready to be put to work in combination with a need or goal, expert experience, and consideration of alternative courses of action. It may be used by individuals, embodied in the documentation, processes, and procedures of an organization, or provided as policy to the policy base of autonomous processes.

Wisdom is a more elusive process, but may be roughly considered as a measure of the effectiveness of knowledge application, in the sense that a wise course of action is one for which a posteriori evaluation renders a positive evaluation of an a priori action.

We will hold as tenets of the IPA project that digital communication links replicate data at a remote location, and data must be put in context to become information. We will not further address the requisites for knowledge and wisdom.

Below is a basic model of the transaction cycle of an Information System. From that we derive a symbolic representation for that cycle. We then proceed to introduce the concept of context, and describe how information is derived from the data and applied to obtain desired results.

[10] René Descartes, from Discourse on the Method, 1637: http://en.wikipedia.org/wiki/Descarte
[11] See Article Wisdom: http://en.wikipedia.org/wiki/Wisdom
[12] See Article DIKW: http://en.wikipedia.org/wiki/DIKW

Figure 5 shows the flow of information in a transaction cycle between two digital Information Process Systems. The originating system on the left experiences a trigger event, and initiates a processing cycle[13] that entails local processing, communication with the recipient system, and further processing on the right, terminating with a result for the Recipient. In this section we will explore how data is communicated and the relationship between data and context in rendering data as information useful to the recipient.

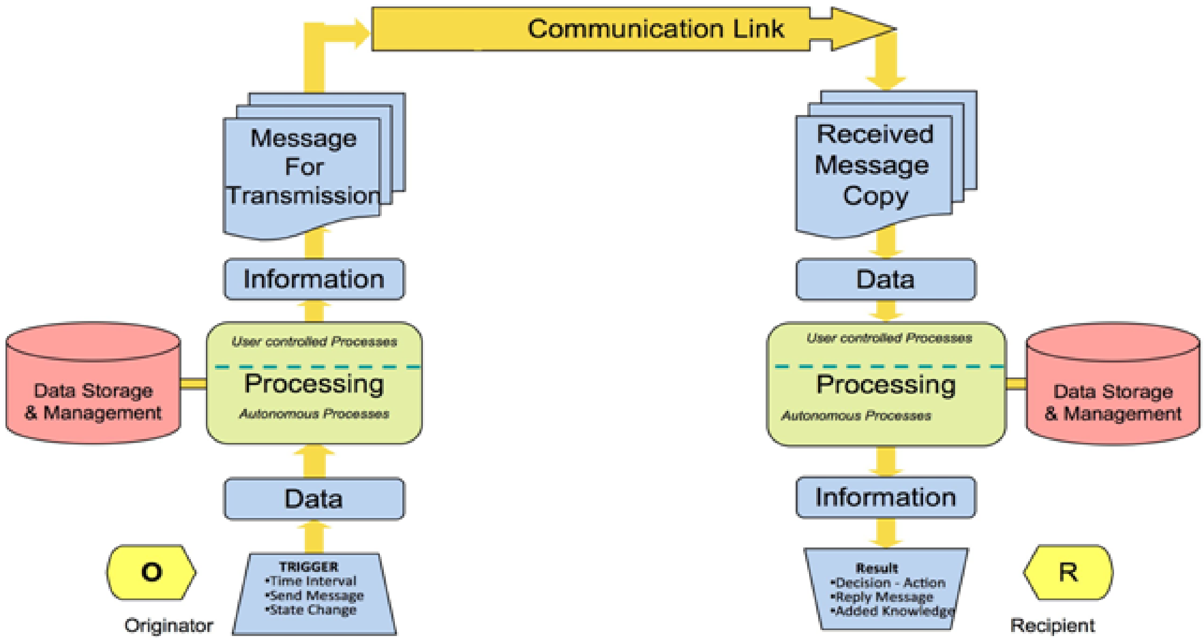

Figure 5. Information System Cycle Unit Model

This Model consists of three parts: Origination (O), Communication (CL), and Reception (R). In its simplest form, the Model portrays a single Originator, Communication Link, and Receiver; we will later consider multiplicity. Similarly, we will start with a single message sent one way is a single transmission over the communication link, and move on the information interchange.

The following sections explain stages of the process.

[13] We will take "cycle" to mean that ordered progression of events In an Information Process System that leads to a Result subsequent to a Trigger.

5.1 Origination

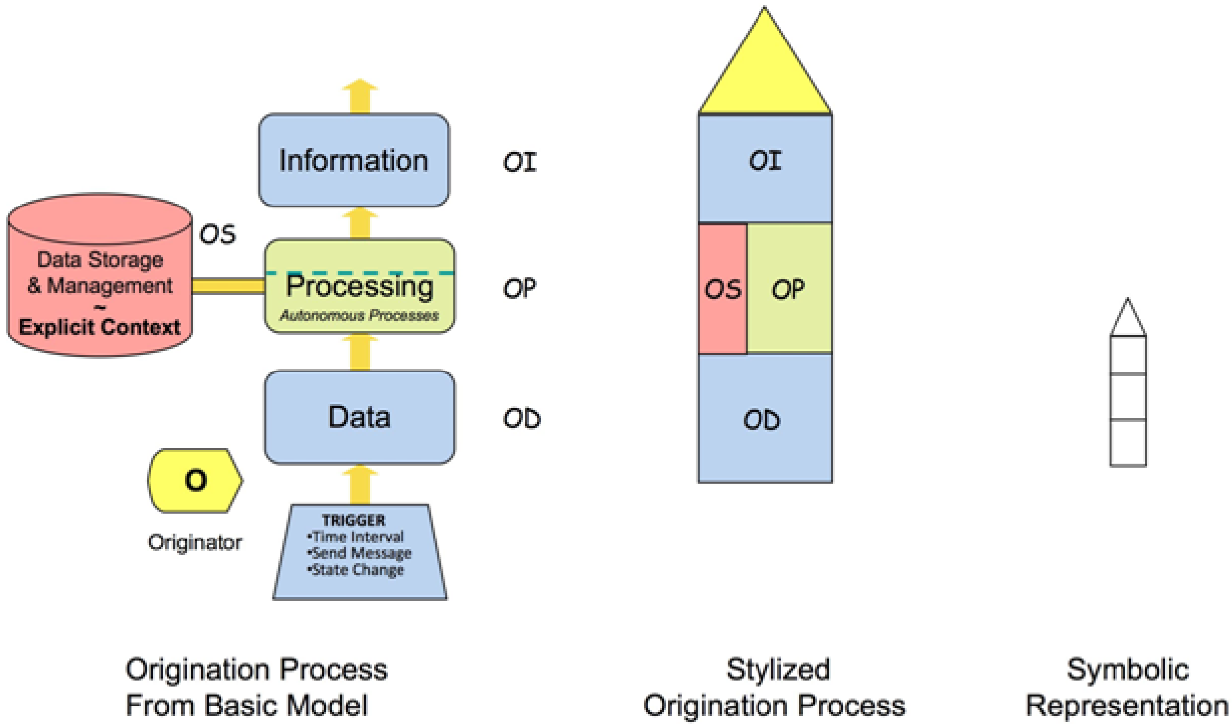

Figure 6. Origination Process of the System Cycle Unit Model

Figure 6 portrays the Origination portion of the model. On the left of Figure 6, individual components are portrayed. In the center is a stylized representation of the components, which serves as the basis for the simplified symbolic representation on the right. We will consider a number of pictures using this symbolic notation and similar symbols for other parts of the Model. It is important to remember that the interior horizontal lines indicate that the symbol stands for all the complexity existing in the original component, and at all times the inherent sub-structure should be kept in mind

The following sections provide details on those functions.

5.1.1 Trigger event

Communication cycle initiation is the result of a trigger. Triggers are events such as expiration of a timer, a change in state of some system element, a change in the ambient RF environment, or composition of an email by a user. The trigger results in introduction of data into the system, and invocation of procedures to process the data. Detailed specification of the data or information introduced varies widely by application

Duration of a cycle varies widely. If the data is a short message, the communication cycle can be very brief. In the case of a telephone call it will be longer, lasting until the users hang up, possibly an extended period of time. The extreme case is broadcasting, such as a television station that stays on the air continually for years, though the "macro" broadcast can be broken into several shorter "micro" data transfers with events back-to-back (e.g., play the first segment of a TV show at a specified time). A mis-scheduling of micro triggers is quite noticeable – dead air – even though the macro-broadcast has continued unabated.

A timed trigger could be a flood gauge on a stream programmed to report water depth every hour, a Smart Grid building electric meter reporting power draw once a minute, an employee submitting a timecard at the end of a week, or scheduled publication time for daily, weekly, and monthly reports. In an automated data processing system, event data is often sent in a fixed format record layout.

The system can be designed to generate a trigger when a designated system entity changes state. For example, radio communication depends on adequate signal strength. In a cellular telephone system, terminal power levels are adjusted when the measured value of the received signal goes above or below needed levels as a result of caller movement.

Setup of a phone call when a user picks up the phone is a trigger that initiates dialing to connect the call, followed by sampling of the analog voice electrical signal originating in a microphone. Analog to digital conversion creates a series of numeric values that are communicated, permitting the language to be reconstructed at a remote location.

An LMR radio user depressing a push-to-talk button triggers a trunked radio call, and all of the radios in a given talk group move to a channel allocated by the system. Ambient temperature over a prescribed value measured by a fire detector triggers an alarm condition, while a similar event in a thermostat activates building air conditioning equipment.

When a triggering event occurs, a record with a defined layout may be generated using the prescribed symbol set arranged in a specific format. Alternately information may be communicated as free form.

5.1.2 Data

Data is the feedstock of information processing, and the volume of data generated and transferred has undergone exponential growth in the past few decades. Many transactions that traditionally involved information conveyed with physical items, such as bank checks and paper books, are now accomplished with electronic communications.

Data is found in the form of a message or transaction; a number of data elements are combined to describe an event or convey a message.

Binary digital communication systems use the bit (binary digit: 1 or 0) as the fundamental element. Data to be conveyed is structured as a string of bits created from rules within a defined data dictionary and specified by the system design.

Data elements vary with the type of data or information to be conveyed, and include:

- Text, made up of words expressed in the alphabet used by the language involved. Each character in the alphabet has a distinctive value, with values concatenated to make up words and paragraphs.
- Digitized speech, represented by a set of phonemes, with different sounds having designated data values.
- Codes used as keys to distinguish individuals among a set of entities. The system architecture must be structured so that each individual entity has a unique code that can be used to unambiguously designate every individual, and as a sort key to group records for each individual. Examples include such designations as employee number, department number, product code, and IP addresses.
- Numeric information, expressed using ASCII numerals, integer binary, or floating point, an integer format with an exponent field to indicate decimal position.
- Ideographs, symbols used to carry a meaning, such as emoticons or Chinese characters.
- Pictures, which may be transmitted as a series of values representing individual pixels (picture elements), often with a compression algorithm applied.

Note that none of the preceding has meaning without the context to understand the bits that define the data.

5.1.3 Processing, Data Storage and Management

If processing is to be done on the data, the elements of Processing, Data Storage, and Management will be next. Static information, such as description or extended codes, may be maintained in the originating system Data Storage and made part of the message to be transmitted. In some cases data averaging or other processing is performed on the data.

As Information is Data taken in Context, Data resulting from the Trigger event must be considered both in context of the system architecture and also in the context that will be applied by the Recipient. As described in Section 4.2, Storage is Data being held in a static environment awaiting future access.

Application Processing, as described in Section 4.4, is accomplished within processes that may be either under user control or autonomous. An important thesis of this document is that, to the extent a system has cognitive functionality, it will be located within the system's Autonomous Processes.

5.1.4 Information

After processing, the Information derived from the Data will be available for use within the originating system. In some cases, all of it will be conveyed to the Communication Link to go to the receiving system. But in many cases some of the information will be treated as context and retained, so not all of it will be transferred as part of the message being transmitted. How much is to be transmitted is a system design trade-off.

When first introduced, corporate computers were used as local data processors, replacing punched card equipment. In a very short time, however, it became clear that using a computer to punch cards or paper tape for transmission of data between locations was not practical or efficient. Very early in the history of computer usage, arrangements were made for one computer to dial up another, and transfer data over phone lines through modems. By the turn of the twenty-first century, such connectivity became a matter of course using the Internet.

5.2 Communication

Communication is the process of accepting data from the Originator (O) and delivering it to the Recipient (R). The communication link may be wireless, wired, or internal to a single node.

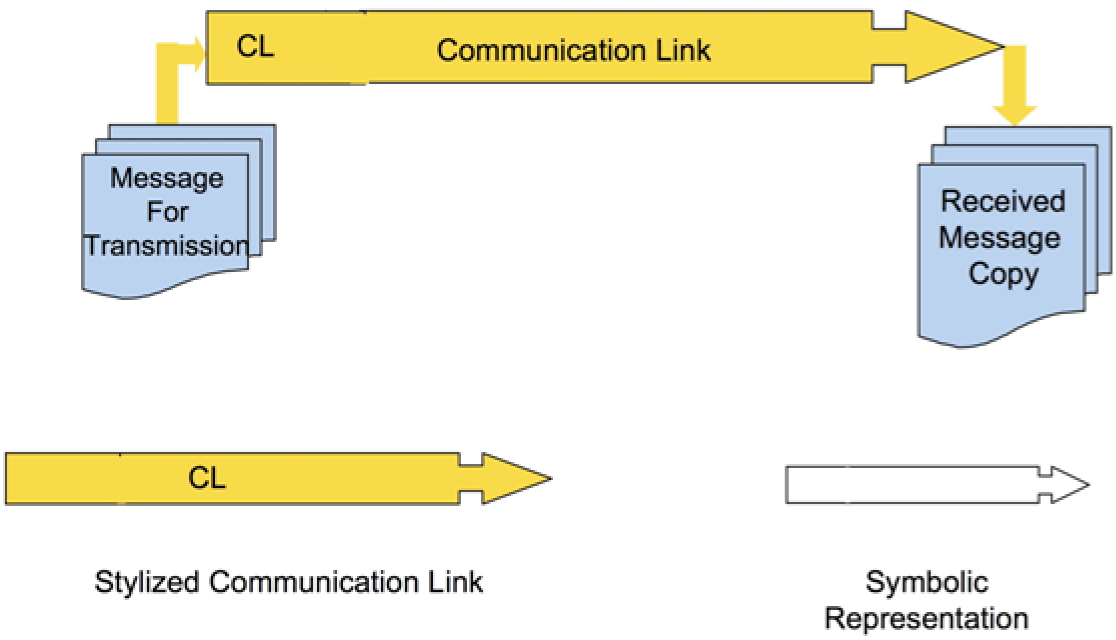

Figure 7. Communication Process of the System Cycle Unit Model

Figure 7 shows the communication link of our Basic Model, again with stylized and symbolic representations.

Digital communication systems utilize real links, capable of accepting strings of bits from the source, and replicating them at a destination. A set of data in the form of electronic bits is presented to the communication port, with an address and other control information. The bit stream is often encrypted for security, and translated to another format to conform with a communication protocol. The bit stream is usually broken into packets of a designated length in compliance with a known protocol, and then conveyed to a destination where the original stream is reconstructed. It is then delivered to the receiving system as data.

In the communication function, data extracted from the Information of the preceding step is sent to the receiving system. It is the responsibility of the Communications Link (CL) to replicate the data accurately at the remote location. If interception of the data is a concern, link encryption and other measures may be applied. Message size, available communication facilities, and need will influence requirements, such as bandwidth, of the communications facility.

CL is a component of a higher-level system. If that overarching system is the communication link of a yet higher-level architecture, then communication processing functionality resides in lower-level R and O functions, and CL represents a lower-level layer in the communication stack.

5.3 Reception

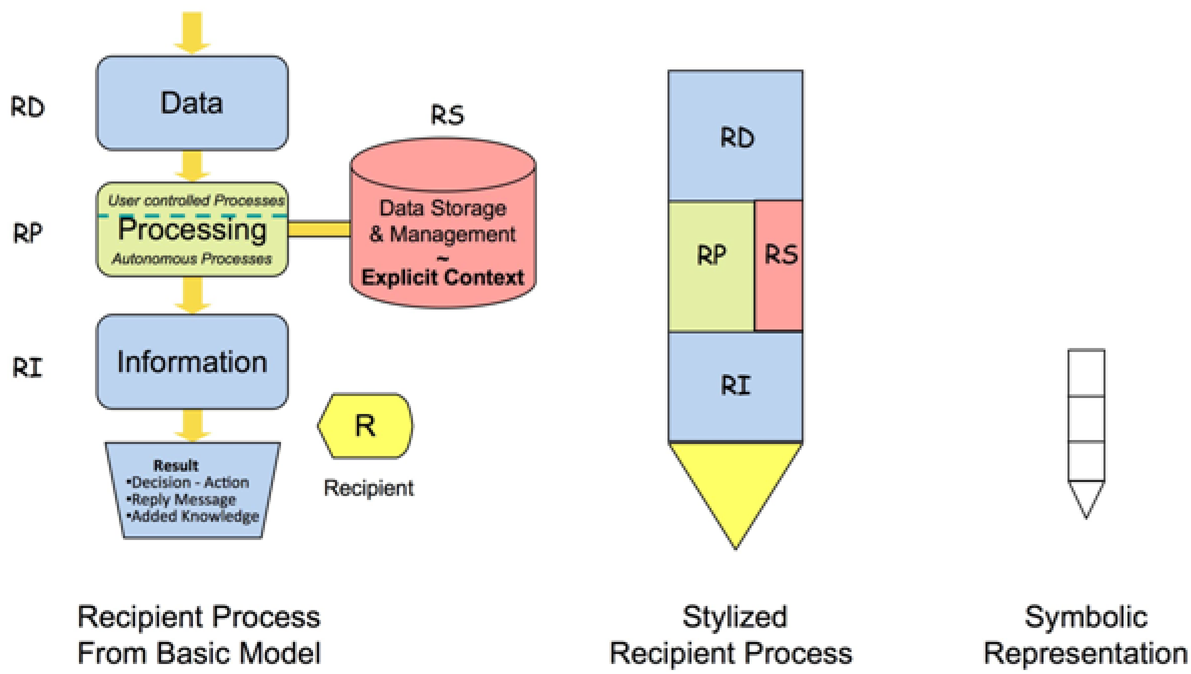

Figure 8. Reception Process of the System Cycle Unit Model

Figure 8 is the Recipient portion of the Basic Model. Its component processes are described in the following subsections.

5.3.1 Recipient Data Processing

Recipient Data Processing performs further processing to put the received data into context, place it into storage, and prepare it for local application use.

5.3.2 Information Delivery

Information delivery converts the received data to information, applies formatting, and delivers the information to a presentation device, such as a display screen or printer. In order to be understood the received data must be placed in context, that is, associated with other data to make a complete package of information.

The information is presented to a user who pays attention to (attends) it or to a recipient autonomous process that acts on the information. When the recipient understands the information conveyed, it becomes part of the local body of knowledge. The recipient is then in a position to make decisions and take action, generate a response communication, or retain the knowledge in memory as part of additional context for future information presentation.

5.4 Message Context

An important consideration for Communication is Context – the information shared by O and R, but not specifically included in the data transmitted over the communication link. Figure 9 is the flow model figure with Contextual elements added.

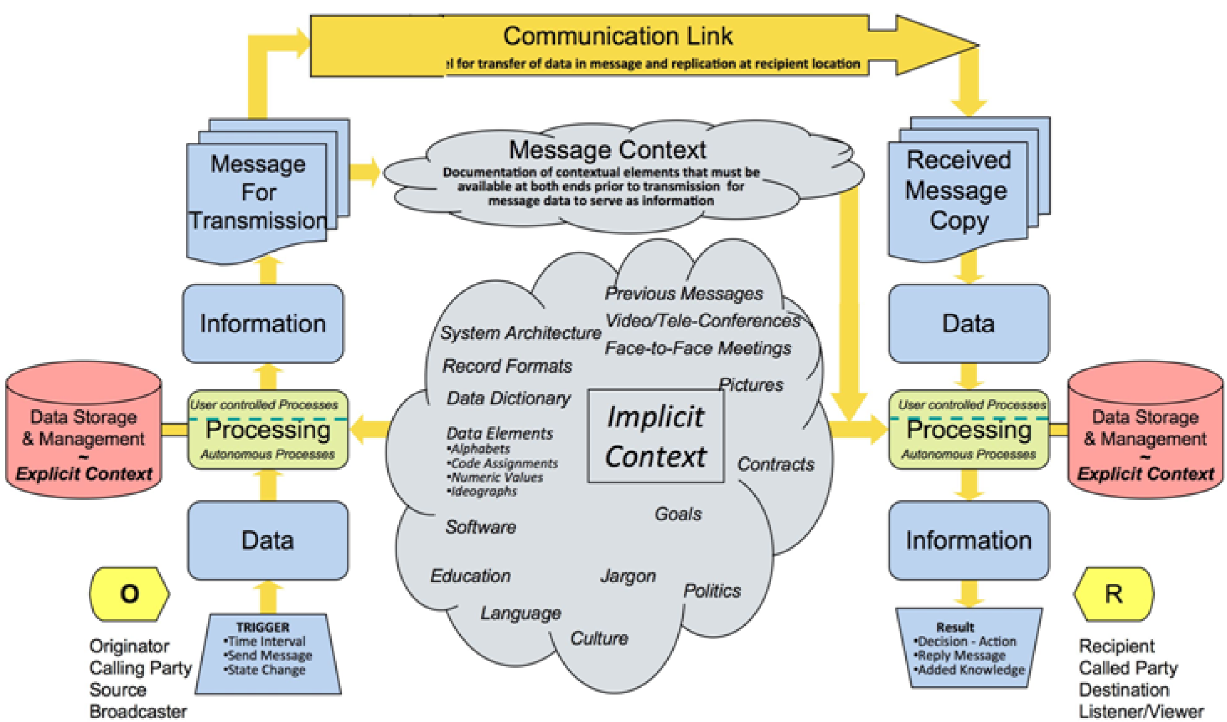

Figure 9. Information System Flow Model with Context

Either Originator (O) or Recipient (R) may be individuals or independent systems. Communication can take place to the extent they share context - information commonly understood.

The most fundamental Context element is language and culture. Unrecognized differences can lead to misunderstanding, while information recognized as incomplete leads to confusion. To the extent O and R do not fully share needed context, a significant barrier to communication may exist, and must be overcome with translation and explanation. Understanding graphic information, such as pictures or symbols, is often less difficult than language and can be used to bridge cultural differences.

A major component of Context is an understanding of the situation from which the message originated. In some cases, such as a novel or motion picture, most needed context is provided. If the two ends are involved in some clandestine activity, then a cryptic phrase (such as "Uncle Bob has come to visit") can carry a prearranged meaning ("Robert Smith, XYZ Corporation CEO has accepted our offer to acquire them"). In transaction processing systems the architecture defines data structures, formats, under what circumstances a given message will be created by O, and how R is to interpret it. A payroll system, for example, receives time card data and issues checks or fund transfers in carefully defined formats.

The ambient goal structure can have significant implications for system architecture, based on whether the two ends have shared goals, independent goals, or are in competition. Communication links provide no electronic shredders, and each message is copied many times as it passes through the buffers associated with multiple links If O and R share goals, then the shared context will be richer, motivation for the message will not be misunderstood, and desired outcomes more likely. In the case of email, care must be taken not to write something in the context of shared goals that could be problematic in a different time and context (e.g., an insider trading legal proceeding).

Most transaction processing systems function under a common set of goals. If a trusted system user, however, develops conflicting goals, most systems are subject to subversion. Encryption adds another element to context; only a recipient with a crypto key can access the data.

If O and R have independent goal sets, then recipients have an additional step in processing the data: determining whether the data is supportive of their goals. That may generate a need for more extensive context, motivation, or justification in the message and lies at the core of the Byzantine problem.

Message Context can be considered meta-data (data describing data); it is a critical consideration of system architecture design to make certain that needed context is available when and where needed to accomplish application goals.

There is a trade-off between data complexity and context. A simple example is provided in Longfellow's "Paul Revere's Ride"[14]: "One if by land, two if by sea" is the rule for how many lanterns to hang from the belfry of the Old North Church. This one bit of information taken in context determined the Americans' tactics.

A terse message is efficient, but increases potential for misunderstanding; transmitting extensive context encumbers the Communication link and introduces increased redundancy, but makes each message more self-sufficient.

[14] Henry Wadsworth Longfellow, Paul Revere's Ride, Atlantic Monthly, 1861; Article Paul Revere's Ride (Poem) http://en.wikipedia.org/wiki/Paul_Revere's_Ride_(poem)

The system can grow more complicated if one considers that the recipient may update its operational Context using knowledge contained within received Messages. This requires an Originator to know precisely what Message Context to provide. The Originator must ensure that the message construct and content is sufficient to convey context to the Recipient, allowing the recipient to understand the Message within the transmission (or at least to provide context for the portion of the transmission related to the Message).

5.5 Observe, Orient, Decide, Act (OODA) Loop

The OODA[15] loop was originally developed by Col. John Boyd[16] as a means for developing tactics for air-to-air combat. It focuses on making fast decisions and taking action in rapidly changing situations. It has since been applied to terrestrial battlefields, Naval engagements, Public Safety events, business market strategy, and notional designs of cognitive radios. In his study and writings, Boyd went deeply into a number of relevant technologies, physical laws, and philosophy[17][18].

Because the OODA loop is often used in characterizing complex systems, it is useful to understanding how it relates to IPA. The OODA loop is complementary to, and consistent with, the IPA concept presented in this document. The OODA loop operates at a higher level of abstraction Col. Boyd originally formulated the OODA loop to primarily consider the thought process of one individual engaging one other individual in combat, and Boyd asserted that the combatant with the shortest and most perceptive OODA loops would prevail. In extending those concepts to other applications, communication of data and information are taken as given, and are not a primary consideration of that model.

While IPA has Information Processes and Communication as its primary area of interest, there are a number of concepts the two concepts hold in common. The following paragraphs describe relationships between components of the two conventions.

Observe. Taken as a stand-alone verb, this word might imply an active observer in control of what was observed. Although Boyd was primarily considering individual minds doing the observing, this phase is quite close to the use of "Scope" in the IPA Framework; it involves setting limits on what inputs can be considered under the circumstances, and in the available time. It correlates directly with the concepts of Trigger and the resulting Data in the IPA Originator.

Orient. The intent of this word is the same as that of Context in the IPA model. It is placing the data in context, transforming it into information, and preparing it for future decision-making.

An interesting example might be a fast-moving cold front impacting the weather at an operational site. If we have a number of sites equipped with meteorological equipment, each can

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[15] See Article OODA loop: http://en.wikipedia.org/wiki/OODA loop
[16] See Article John Boyd (military strategist): http://en.wikipedia.org/wiki/John Boyd (military strategist)
[17] ibid. Boyd invoked (among others) Gödel's Incompleteness Theorem, Heisenberg's Uncertainty Principle, Kuhn's views on Scientific Revolution, and the Second Law of Thermodynamics.
18 Also see ibid, Boyd, John, Destruction and Creation

report current conditions on a schedule, such as hourly, that reflects normal rates of change, such as those arising from diurnal heating and cooling. With frontal passage, however, comes a sudden drop of temperature, rise in barometric pressure, and significant shift in wind direction. Each measuring station can determine the time of passage with some precision by watching these changes, and issue a nonscheduled event giving the time of frontal passage. A central site can take a number of such messages, and predict when passage and the associated wind shift will occur at an incident site.

Decide. The IPA model considers the Communication that takes place at this point, whereas OODA usually does not. Both recognize emergence of Information from the communication and further processing at the Recipient's location in preparation for decision-making. The result is a new set of goals and objectives that are intended to result in state changes in the environment.

Act. The final step in both cycles is issuance of directives, commands, signals, or recommendations to instigate the changes needed to approach the new goals. Then the cycle goes back to the next Trigger, or to further observation of results of the new actions.

So, the OODA loop emphasizes speed and skill of data collection and decision-making; IPA emphasizes Communication Quality of Service (QoS), ensuring the proper context, and the resulting speed and accuracy of information delivery.

5.6 System Structure Notation

System Structure Notation (SSN) is a symbolic representation based on the Basic System Model described above. The purpose of SSN is to provide a readily understood, high-level description of how the architecture functions. It is similar in concept to a civil Architect's rendering of a proposed building. These diagrams are used to orient and focus detailed discussions. Their main utility is as a facilitator for human communication, and they are intended for use by System Architects and system users.

Figure 10 is a symbolic representation of the Basic Model as shown in Figure 5. It depicts the same O, C, and R components. Line segments inside the symbols are a reminder that they are representative of the more complex structures in previous figures. The descriptions provided in Sections 5.1 - 5.3 apply, but this view has them abstracted in order to provide a clear view of system component relationships.

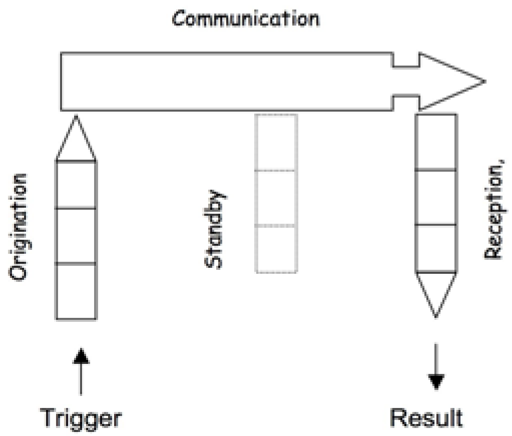

Figure 10. Symbolic Representation of the IPA Basic Model. Note Standby is not part of the Basic Model, but is used to represent and entity in a state to be activated by a Trigger in Originate mode or by arrival of a communication to be activated in Receive mode.

In these diagrams, black outlines indicate active components, while grayed-out lines indicate elements that are not currently participating in system operation. A new type of symbol, "Standby", is also introduced. In some systems to be considered, a terminal may be inactive, ready to participate as either an Originator (PTT is depressed) or Recipient (they are addressed over the air).

The following SSN Diagrams are intended to show how this notation can be applied to Information Process Systems. They are part of the Structure element of the Information System Framework described in Section 3.1.

5.6.1 Amazon Kindle[19]

Figure 11 is an application example of an SSN diagram using the basic model. It shows how the popular Kindle Reader interacts with the Amazon Store where new reading material is obtained.

[19] See Appendix B, Section 9.1.

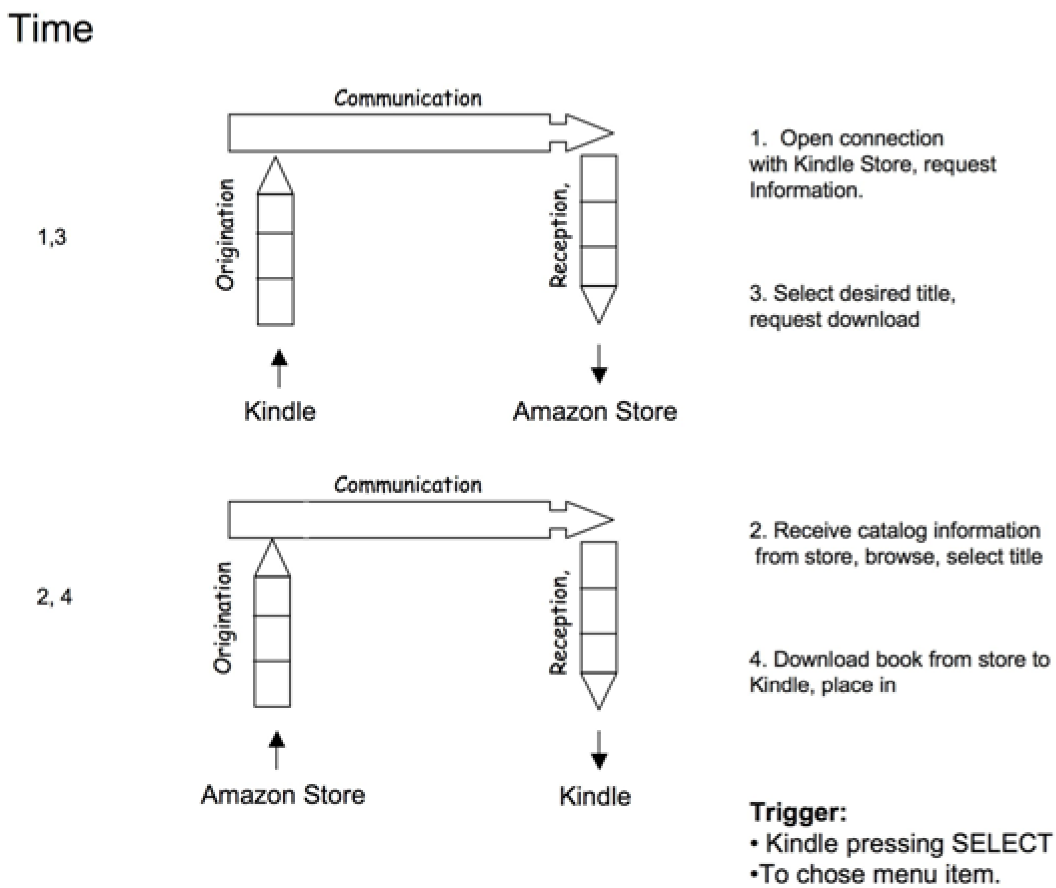

Figure 11. Amazon Kindle Transaction Processing SSN Diagram

Although this diagram is quite simple, we will use it to make several points. The first is that written explanation of the picture is essential. The diagram is nowhere near self-explanatory; it is presented to display relationships and supplement the textual description. Events relating to each diagram are conventionally placed adjacent to corresponding diagram. Multiple events can relate to a single diagram to avoid unnecessary clutter.

In this case, the sequence of events is presented on the right side of the diagram, numbered 1,2,3,4 to represent the sequence of occurrence. Numbering is not required, but can be used to clarify event sequencing. Events 1 and 3 reference the upper diagram, while events 2 and 4 are illustrated by the lower diagram as indicated by numbering on the left under the heading “Time”.

The second point is that these diagrams are holistic; they can function at a number of different levels of system consideration. In the example we will examine a middle-level consideration of a Kindle transaction cycle, purchase of a book.

The cycle consists of opening a connection, selecting a book, and downloading it. The triggering event is accessing the Amazon Store entry from the unit’s main memory. The end result is the book in digital form in the unit’s memory with an entry in the Kindle Home Page.

These representations are general and notional, not rigorous or precise. Their primary intent is to provide a readily understood representation of a series of activities that are quite detailed at the lower levels; the intent is to shield the high level viewer from that complexity.

Each of these activities occurs at a point in time, so multiple figures are required for a time sequence. The roles of Kindle and Amazon Store change activities between Origination and Reception as the cycle progresses, and the communication channel reversed direction.

5.6.2 Cellular Telephone[20]

Figure 12 is an SSN representation of a call from one mobile phone to another over a GSM network. Some of the terminology is specific to cellular systems, but the user is assumed to be familiar with the meaning. If that is not the case, the precise meaning of acronyms should be provided in a separate section.

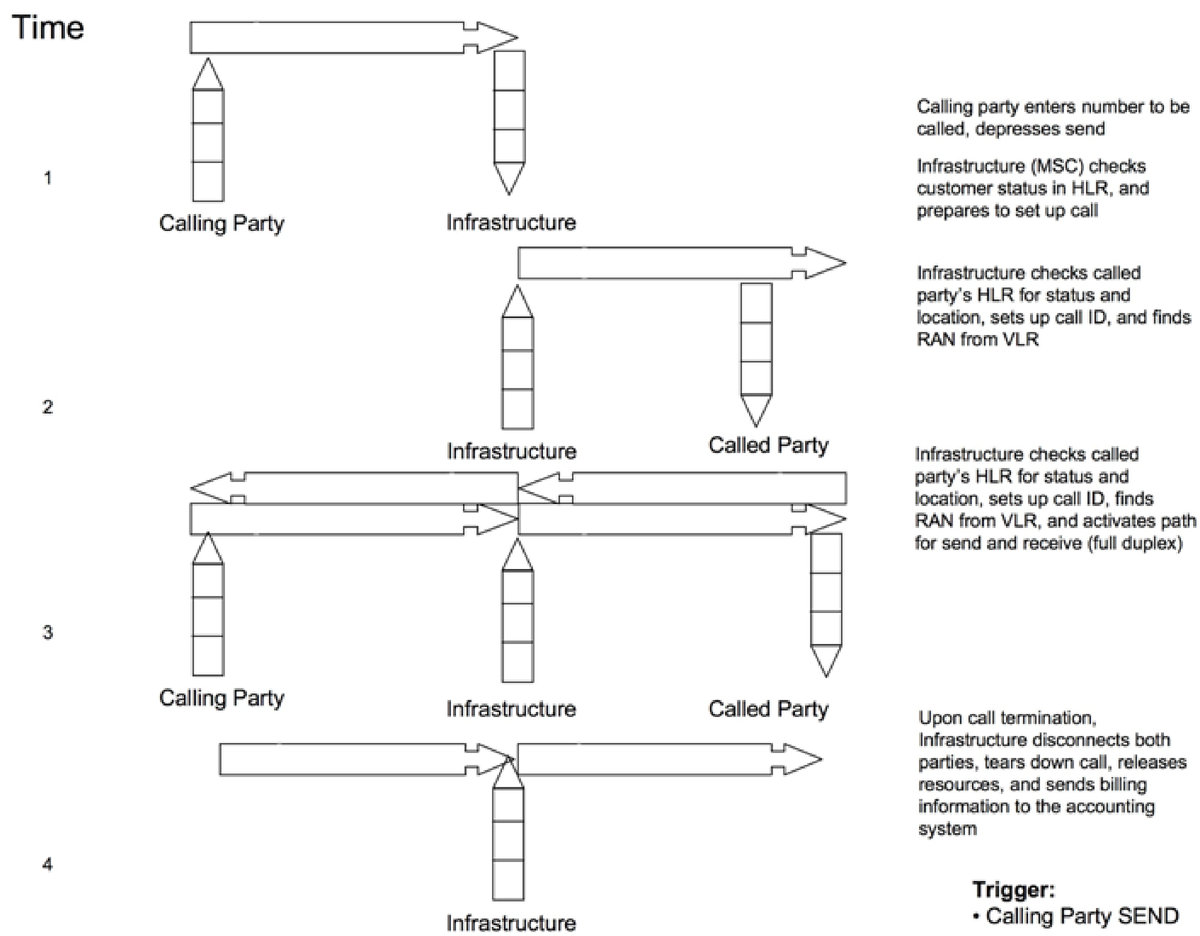

Figure 12. Cellular Telephone SSN Diagram

[20] See Appendix B, 9.3. Cellular Telephone

The sequence starts with the calling party pressing SEND. The other mobile phone is located, and a connection set up. When the conversation is complete, the parties press END, and the call is torn down.

5.6.3 Trunked Land Mobile Radio[21]

Figure 13 depicts an SSN diagram of a trunked land mobile radio voice transaction. It represents a message trunked system, as that is a common type of system.

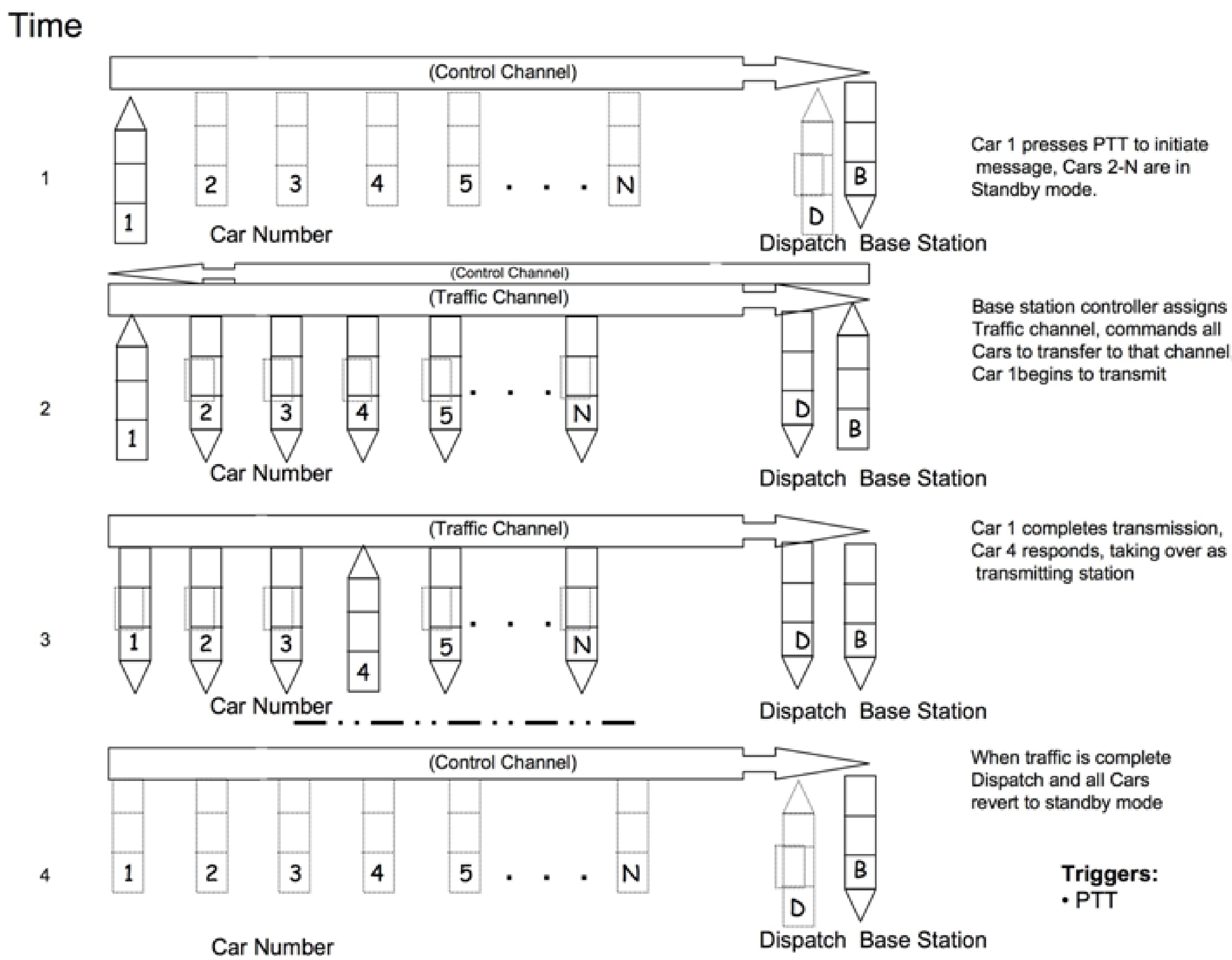

Figure 13. Trunked Mobile Radio SSN Diagram

A number of "Cars" (a common designation for any remote mobile terminal) are deployed under control of a Dispatcher and a high-powered central transmitter site. When any terminal initiates a call, all of the radios of members of that Talk Group are directed to switch to an available traffic channel. Operating in half-duplex mode (often with local abbreviations that require context to fully understand)), they talk, and when the transaction is complete, all remote units return to a quiescent state. There they listen on the control channel for further instructions.

[21] See Appendix B, 9.2 Trunked Land Mobile Radio

5.6.4 Television Broadcast[22]

Figure 14 shows a Television broadcast station serving a large number of viewers. A station applies for and receives a license to transmit on a specific channel. It then broadcasts continuously on a fixed schedule, often 24 hours per day. Viewers come and go as they desire. Time 3 represents a narrow bandwidth voice feedback through a call center that receives calls from viewers making contact to pledge financial support or buy products offered on a store-like shopping program.

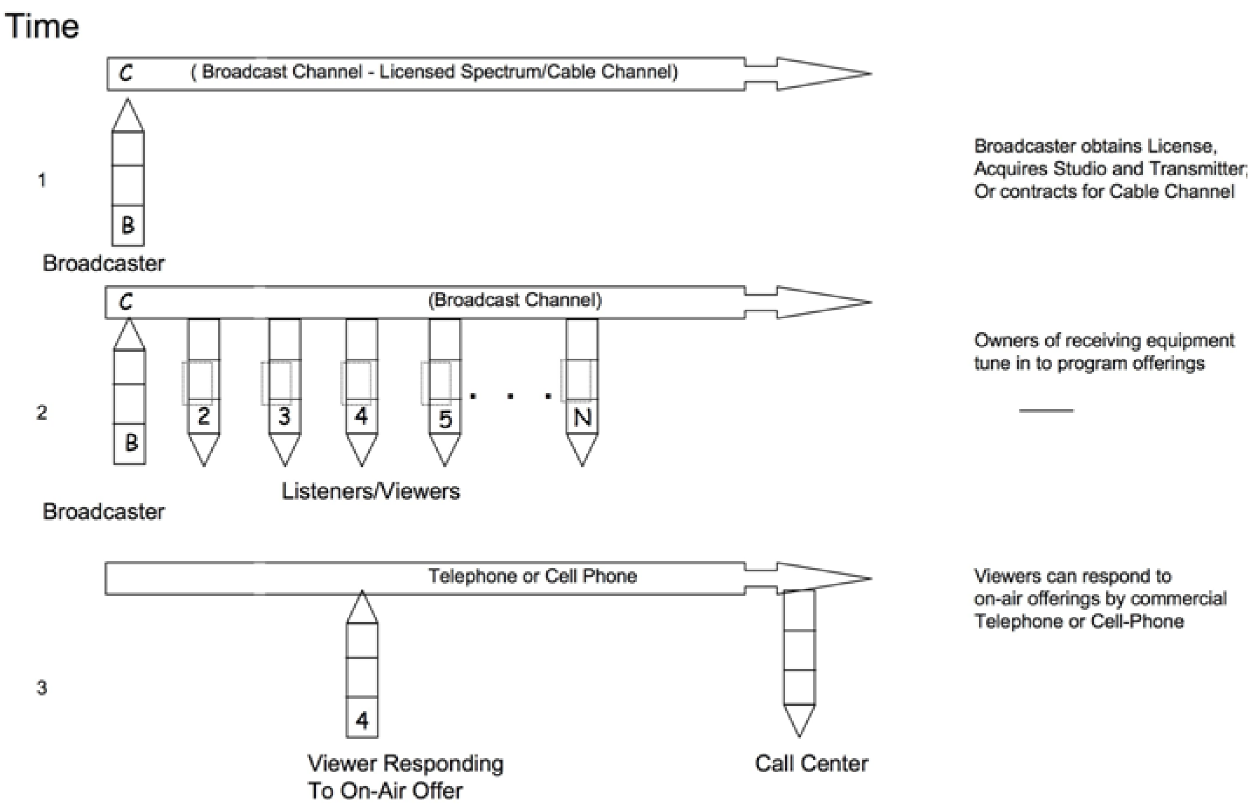

Figure 14. Television Broadcast SSN Diagram

5.6.5 SSN Summary

These diagrams are included here as examples of SSN notation. In Section 5.7, we will observe that this approach is one of a number of ways to depict System structure and behavior. In future IPA work of the IPA Project, a more complete presentation will be made of a set of Views, or Products, that can be used to document systems. Again, an objective of the IPA project is to facilitate understanding of independent systems as they intersect to form complex systems.

[22] See Appendix B, 9.4 Television Broadcast

5.7 The IPA Unit Cycle Model in Other Representations

Presented in his section are a number of views that are alternate representation of the simple transactions presented above. They are examples of alternate views that can be used to highlight important aspects of system architecture, provide emphasis on certain aspects of system entity interactions, and to aid in understanding of system functionality.

Figure 15 emphasizes the actors in a transaction cycle, and describes initial and final conditions. Actors and their interactions are identified.

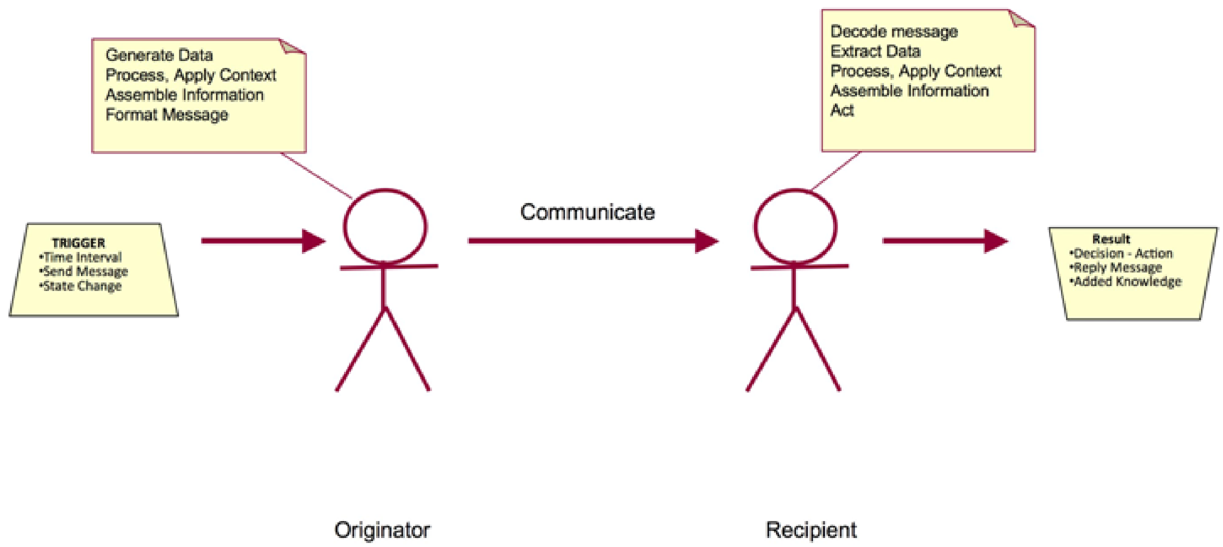

Figure 15. System Interaction Diagram

The ladder diagram in Figure 16 identifies the actors and emphasizes the sequence of interactions over time. It makes sequencing clear, but is awkward when conditional decisions result in multiple event sequences.

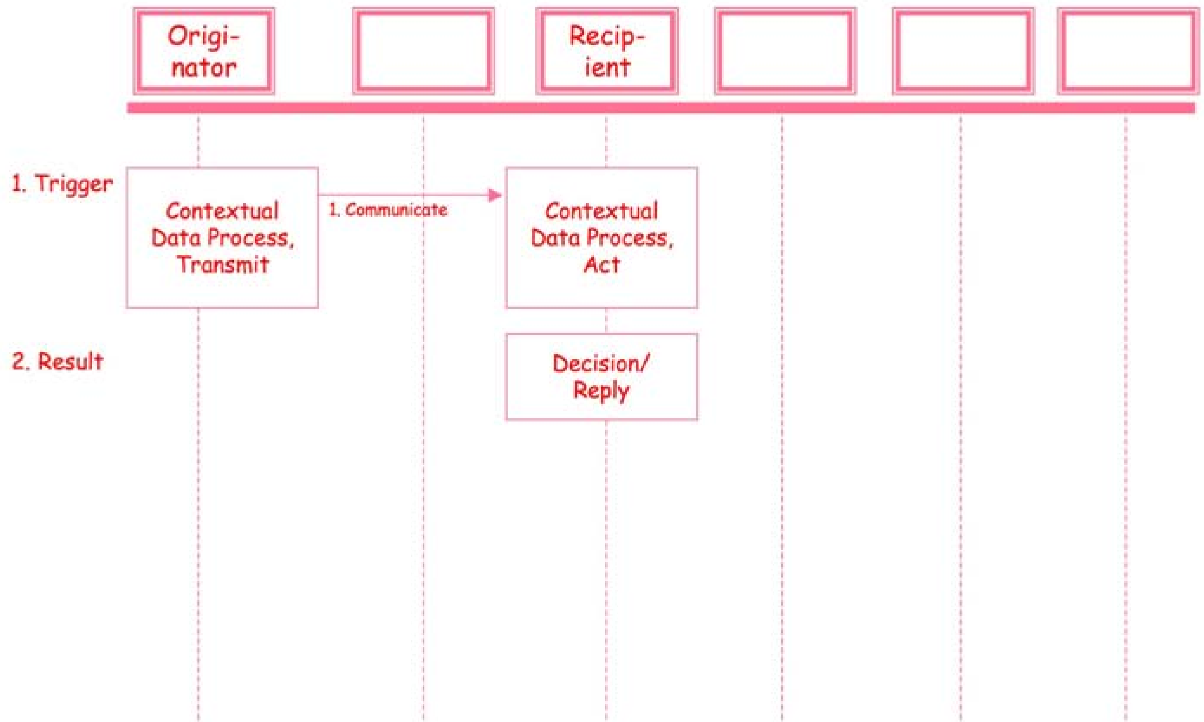

Figure 16. Process Interaction (Ladder) Diagram

The State Transition Diagram, as shown in Figure 17, emphasizes system states, and identifies events that initiate transition between states. This representation is very effective in presenting conditional variations in state transitions. This particular diagram is unusual in that there are no states that originate multiple arrows due to conditional decisions.

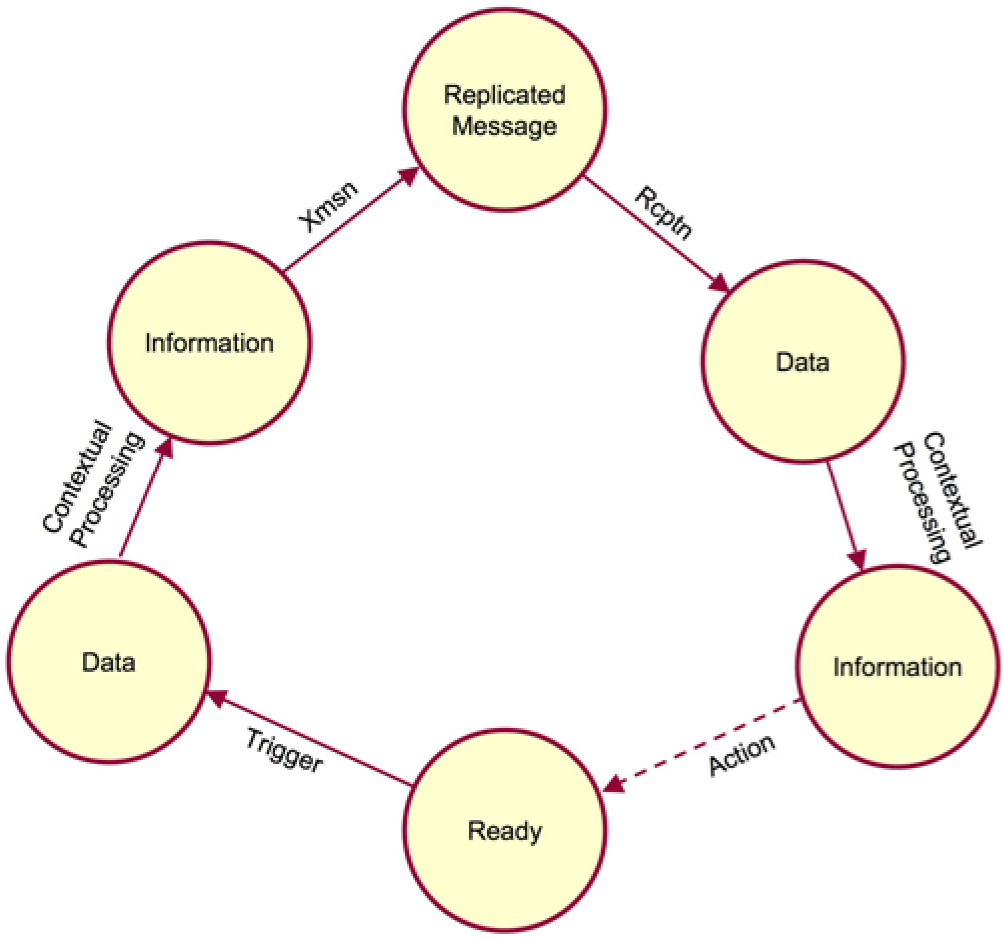

Figure 17. State Transition Diagram

As an architectural concept, a single transaction cycle is at quite a high conceptual level. Beneath that level are a number of layers with increasing detail and complexity. Use of appropriate views can be quite useful in coping with variations in nomenclature and representation techniques between independently developed components of emerging complex systems.

6 Future Work: Information System Views

A great deal of work has gone on since the introduction of automated data processing to characterize their architecture and an analogy can be drawn between documenting information systems and physical structures. Just as the plans for buildings have plan views and elevations, documents describing an information system architecture contain different views. A primary goal of the IPA project is to propose such views. Future documents of the IPA Project of this document will present the result of that work.

To preview this work, this Section presents a group of traditional architectural views considered for documenting the IPA. Characteristics of those views include the following:

- The component systems required for the process to work can and do operate independently.
- They were acquired separately and maintain a continuing operational existence independent of the complex system they participate in.
- The Information Process and its architectural rendition is never fully formed – its development and existence is evolutionary with functions and purposes added, removed, and modified over time.
- There is a wide/large geographic extent. Note: wide or large implies that only information can be exchanged between the component systems, not energy or mass.

These characteristics demonstrate the complexity of the Information Process, and an attempt to document the 100% solution is futile – it is simply too difficult to wrap one's arms around it all. Architectural products provide a venue for depicting the structure of component systems, their relationships, (e.g., the organization of information sharing across diverse and sometimes competitive user communities), the technical aspects of data collection and presentation, and guidelines governing their design and evolution over time. The result is an architectural framework with views that accommodate those approaches, models, and definitions that are needed to communicate and facilitate the presentation of key architectural information. The views describe architecture vision, principles, guidance, processes, and other characteristics, and establish a common foundation for understanding, comparing, and federating the information process.

There are a minimum of three architecture frameworks that need to be evaluated. Regardless of those employed, certain architectural views are necessary to portray the various levels of system and user interaction. The authors believe the framework for the Information Process Architecture should be drawn from all frameworks currently in use.

6.1 Above All Views (AVs)

Regardless of the intended use of the architecture, an AV documents assumptions, constraints, and limitations that may affect high-level decision processes for a specific architecture. AVs document viewpoints from which the architecture is developed and the architecture's context, i.e., the vision and the tasks being accomplished by the user communities, doctrine and policy, concepts of operation and circumstances under which the complex system users and systems are assembled to do something. They identify start and stop dates, level of effort and costs necessary to develop the architectural products and the user communities that perform activities. Most importantly, AVs provide textual definitions – e.g., a glossary, the repository of architecture data, taxonomies and their meta-data (data about the architecture data). AVs offer the common lexicon and dictionary from which all architectural product users base their interpretations as well as a central repository for a given architecture's data and metadata – thus enabling architectural products to stand alone, allowing them to be read and understood with minimal reference to outside resources.

6.2 Operational Views (OVs)

Operational Views describe the tasks and activities required for information to be processed successfully, the participating users and the operational nodes where user activities take place and the associated information exchanges. The descriptions found in OVs are the vehicle for:

- Examining business processes for reengineering or the insertion of new technologies (e.g., Cognitive Radio).
- Identifying training needs for the user community.
- Exploring the implications of doctrine and policy.
- Coordinating the myriad user relationships.
- Defining the high level requirements that need to be supported by resources and systems (e.g., communications throughput, specific node-to-node interoperability levels, information transaction time frames, security protection, etc.).

6.3 Systems and Services Views (SVs)

A "system" can be thought of as a compilation of resources and procedures united and synchronized by interaction or inter-dependence to facilitate the user's completion of an activity. Services, a unit of work done by service providers – frequently software agents – are offered by providers and used by the consumers while performing activities within the process; both provider and consumer are roles played by agents on behalf of their owners.

Systems or Services Views describe the systems and services of concern and the connections among them as they relate to the OVs. The SVs are developed to establish the complex system's baseline, make investment decisions concerning cost-effective ways to meet the user's operational requirements as well as evaluate the state of the complex system's interoperability and/or make interoperability improvement recommendations.

6.4 Technical Views (TVs)

The Technical Views provide the basic set of rules governing the arrangement, interaction, and inter-dependence of system parts or elements and assist in ensuring that a system satisfies operational requirements. The TVs provide technical systems implementation guideline(s) upon which engineering specifications are based, common building blocks are initiated and product lines are developed. These views include a collection of the technical standards, implementation conventions, standards options, rules, and criteria. Technical views can be thought of as the technical standards criteria governing the implementation and integration of the selected systems. Technical views offer opportunities to articulate the technology and implementation roadmaps for the complex system's integration approach or individual system development.

6.5 View Summary

The various views fill the requirements of the users, new system designers and the support plans to perform the following:

- Describe what needs to be done, who does it, the information exchanges required to get it done and the operational activities performed by the system users. (OVs)
- Relate specific system functions required to satisfy the information exchanged and those specific systems providing it. (SVs)
- Identify/prescribe the standards for integrating existing systems as well as what new systems must meet. (TVs)

- Set the tone for the overarching aspects of an architecture that relates to all three views and set the scope and context of the architecture. (AVs)

7 Summary

Our society is teeming with information systems that are changing the way we live and work. Systems emerging from different sources and application areas appear to be quite independent and different, each with its own motivation, vocabulary, and implicit assumptions. However, the IPA builds on the axiom that such systems often have similar underlying foundations and even use similar technology, though without acknowledging their similarity. Pointing out the common ground between these systems, providing the means to clearly describe the commonalities, and describing how these systems interface and are applied to create more sophisticated applications are major goals of the IPA project.

Herein, we observed that systems exist in a number of tiers or levels and pointed out that understanding those levels becomes increasingly critical as our information system goals require the integration of a growing number of systems.

We looked at the impact of several revolutionary technologies over the past two hundred years, and proposed that our future will hold additional significant revolutions. In particular, the current epoch – the information age – is beginning to be supplanted by an age of intelligent systems as we incorporate autonomous intelligent processes into our information systems. While this world will lead to capabilities unlike any we have seen before, we have been through several revolutions in our systems over the last two hundred years and understanding the past will be helpful in preparing for the significant challenges of the future.

This document helps provide this understanding by introducing a Framework for describing information systems and how they incorporate intelligent, autonomous processes. By considering Purpose, Scope, Technology, Economics, Politics, and Structure, this Framework allows us to find out a great deal about the fundamental motivations and operations of the system in terms of its environment and position in society without invoking legacy constraints that may inhibit progress.

This Framework was explored further to define a notational system that describes the transfer of data, information, and context from an Originator to a Receiver (whether human or autonomous processes) to facilitate the sharing of knowledge. This notational system can be described as a fundamental cycle of events, in which a triggering event initiates a series of activities that result in an Originator using a Communications Link to transfer data to a Receiver, who puts that data in context to become information, and that knowledge may serve as a new triggering.

Due to time considerations and the vastness of the issue, this document could not fully address this topic. Creating a more rigorous architecture for describing complex systems of information systems, identifying common types of interfaces and standard deployment scenarios, defining a systematic approach to identifying an information system's needs and opportunities for third parties will be explored in future efforts. In particular, testing these concepts against practical systems to refine views and to identify the value-added that the Intelligence epoch will enable via Knowledge systems is a focus for the Work Product and Views for later phases of the IPA Project.

8 Appendix A. Bibliography

We have found the following books of interest in the area of general systems, and they have influenced our thinking about the essence of Information, Information Systems, and nature of "Cognitive Radio" and in this effort in particular.

Bill Bryson, A Short History of Nearly Everything, Broadway Books, 2003

Lots and lots of data about how improbable it is that we are here at all, and how little we understand about the universe (macro) and subatomic (micro) worlds. A great read, and full of numbers and facts.

Nicholas Carr, The Big Switch, Rewiring the World from Edison to Google, W.W. Norton & Company, 2008

This book describes the evolution from steam power through electricity to distribute that energy to the World Wide Web as it evolves into the World Wide Computer. Digital communication has replaced most written forms of information, with major impact on banks, stores, businesses, schools, newspapers, and even the Post Office. Everything we do on a computer has potential to be collected and analyzed - privacy has become an illusion. At some point in the future everything will be integrated, and that point is no more than a few decades away.

Clayton Christiansen, The Innovator's Dilemma, When New Technologies Cause Great Firms to Fail, Harvard Business School Press, 1997

The author identifies two modes of change, evolutionary and disruptive. Large successful organizations often enjoy years of successful operation, respond to customer needs, and invest in further developing technologies critical to their business. Then a disruptive technology, often introduced by a startup, triggers a dramatic shift in the market often leading to complete failure.

One example is the way personal computer manufacturers displaced mini-computer companies at the end of the twentieth century. Another is the transition from mechanical cash registers to computerized point-of-sale credit card terminals.

C. West Churchman, The Systems Approach and It's Enemies, Basic Books, Inc. New York, 1979

Churchman is one of the philosophers who came back from WWII with experience in Operational/Operations Research. He was also co-author of Introduction to Operations Research with Arnoff and Ackoff. OR was one of the big buzz-words in the sixties, and when it grew up came to be called General Systems. (Disclosure: the PhD I didn't manage to complete was in General Systems from Portland [Oregon] State Univ.) Churchman bridged engineering, mathematics and philosophy, and was strongly influenced by Kant (who wrote in German, and is fundamentally incomprehensible in the original). The titular enemies of the systems approach are Politics, Morality, Religion, and Aesthetics. He discusses the fallacy of ignoring the environment, consequences of ignoring history, and the complexities of the "Transcendental

Dialectic" (it gets a bit deep here) that he used in determining anti-U-Boat strategy during the war.

R. G. Collingwood, An Essay on Meta-Physics, University Press, Oxford, 1940

Collingwood was an Oxford Professor with a way of making complex philosophical issues quite clear (e.g. Kant's Critique of Pure Reason). He discusses "presuppositions" in great detail: these are unchallenged assumptions, positions that people hold without specifically identifying them, when they discuss issues. Of particular interest is his study of "absolute presuppositions"; that which is believed when an individual traverses back along a chain of presuppositions until he can go no further.

The Data Management Association, The DMA Guide to the Data Management Body of Knowledge, 1st. Edition 2009

Collaborative work of a large number of DAMA members. A comprehensive and detailed look at the functions involved in data management in the context of a large enterprise.

Thomas S. Kuhn, The Structure of Scientific Revolutions, University of Chicago Press, Chicago, 1962

This famous book is a discussion of what scientists believe and why they usually can't change in the face of overwhelming evidence that their paradigm is wrong.

Ray Kurzweil, The Singularity is Near, when Humans Transcend Biology, Penguin Books, New York, 2005

This book is a blockbuster. It analyzes the human brain as a computer: slow but massively parallel, and evolving at a slow linear rate. It traces the exponential growth of computer capability, and presents the mathematical certainty that the latter will surpass the former prior to 2040. He predicts that our genetics will evolve toward interconnection with machines, that Nanobots in our bloodstream will provide neurological communication to the net, and developments in robotics will replace human activity in many areas.

He has a detailed explanation of how Artificial Intelligence started, went underground, and emerged as the hidden basis for behavior of the world around us. Cars, computers, cameras, and kitchens are already AI applications. The Web will tap into our own nervous systems, and we will have every sensation of physically being somewhere rather than watching it on TV.

These final conclusions are both uncomfortable and scary to read. What if our integration with the information infrastructure is not as benign as he suggests?

Nicholas Negraponte, being digital, Vintage Books, A Division of Random House, New York, 1996

Negraponte, Founding Director of the MIT Media Lab, introduces the concept of bits and atoms as fundamental building blocks of information and physical things. The material is now fifteen years old in a market where three years is forever; in spite of being five forevers old, it provides deep insight into where our information inundation came from. Thinking in terms of a future of free disk storage and unlimited computer cycles, it provides both perspective and insight to help us conceptualize the systems of the future.

Everett M. Rogers, Diffusion of Innovations, Fourth Edition, The Free Press, A Division of Simon & Schuster, New York 1995

This is the culminating volume in a legendary series of books resulting from Rogers studies of the diffusion (and rejection) of innovations. He invented the term "early adopter", and meticulously documented the result of his and other's research in formulation of a bell curve of categories of acceptors, ranging from "Innovators" to "Laggards". The four volumes are quite different in character, representing the maturation of Rogers's views.

The first three volumes, all published by the Free Press, are:

- Diffusion of Innovations, 1962
- Communication of Innovations: A Cross-Cultural Approach, 1971, with F Lloyd Shoemaker
- Diffusion of Innovations, Third Edition, 1983

Stephen Wolfram, A New Kind of Science, Wolfram Media, Champaign, IL, 2002

Wolfram, author of the Mathematica software, has a 1200 page tome about cellular automata and its application to a wide range of areas, including plant and animal growth, crystal structures, logic, geometry, arithmetic, philosophy, and much more. He identifies 256 "rules" for propagation of squares starting with a single black square in the top row. Each rule has eight boxes indicating the resultant from each combination of black or white for a cell and its neighbors on the previous row. Only a few of the rules show interesting behavior, but the resulting complex and unpredictable behavior sheds new light of the meaning of determinism.

9 Appendix B. Framework Source Systems

A number of different types of information processing systems have been considered in development of the IPA System Framework. In Appendix B we describe eight such application systems using the Framework Structure. The intent is to demonstrate how the Framework can be applied to a variety of information systems.

9.1 Amazon Kindle

9.1.1 Purpose

Communication of information is replacing shipment of physical objects in a number of markets. Kindle is Amazon's attempt to automate delivery of books. Amazon has created a digital bookstore where "books" are delivered to users in the form of a digital file. Reading the book is accomplished by displaying the file as text and graphics on a convenient terminal. Amazon's own Kindle is a handheld terminal about the size of a small soft-cover book, which is easily read and can store hundreds of books in its memory. The system uses Sprint's commercial data network to permit browsing the Kindle Store, and to download books on demand.

9.1.2 Scope

The system originally consisted of the Kindle Store, use of Sprint data network, and the Kindle device. Scope has since been expanded to provide software for a number of other terminal devices to enable them to access the Kindle Store and download books.

9.1.3 Technology

Amazon has arranged to make hundreds of thousands of books available in digital format to Kindle Store customers. The look and feel of the regular Amazon website prevails on the store, with some adaptation to the limited black and white screen of the Kindle. Technology for book storage, user selection, and delivery over the Sprint data network is a normal evolution from previously existing systems.

The original Kindle device[23] consisted of a five by seven and one-half inch handheld unit with a three and one-half by five inch screen using digital ink technology. Software has since been made available to use the Kindle service on a number of other devices, including the Apple iPod.

9.1.4 Economics

The Kindle user must subscribe to the Kindle service, and purchase a Kindle for several hundred dollars or use their own terminal. Newspapers and articles purchased on the service cost $.99 or more. Most books cost $9.99, with text and reference books costing somewhat more. Network access is provided at no extra cost. 35% of list-price goes to the author and publisher for each sale.

9.1.5 Politics

As the service uses existing licensed service providers and the Internet to communicate with clients, there is very little controversy surrounding communications. Intellectual rights have been a major problem in many fields of artistic endeavor. Amazon has approached this problem by positioning its channel as incremental sales, and by sharing revenues with copyright holders.

Unlike a book, the purchaser does not buy the material; he licenses a digital copy of the work and the right to read it. It cannot be "loaned" to another party -

[23] See article Kindle: http://en.wikipedia.org/wiki/Kindle

9.1.6 Structure

Amazon has a very large system for on-line purchase of books and other goods. The Kindle unit contains a commercial cellular data radio. Whenever the user contacts the Amazon store, data is transferred from the local unit through the cellular system to the central Amazon system. When a purchase is made, the desired book or article is delivered by data transmission through the commercial system at no additional cost to the Kindle owner. The purchase cost is charged to the owner's on-file credit card.

9.2 Trunked Land Mobile Radio

9.2.1 Purpose

Land mobile radio systems, frequently used by public safety and other municipal departments, are characterized by high-powered base stations with tall antenna towers, a network that ties them together into a unified system and provides/collects information to/from the system users, radios used in vehicles (called "mobiles"), and radios carried by the personnel (called "portables"). Because of the critical nature of public safety communications, a very high level of service availability is required, with excellent voice quality typically required over at least 95% of a jurisdictional (service) area, and rapid (less than .5 second) system access times. Also, high reliability is demanded; neither radio nor communications failures are tolerated since life or death can literally depend on the user's ability to communicate.

To prevent unauthorized use or monitoring of public safety communications by the "bad guys", considerations in regard to system security and communications confidentiality are also often paramount.

LMR systems utilizing Trunking technology are typically employed by the municipalities with large numbers of users. Trunking is an approach to spectrum utilization whereby radio users are organized into talk groups. When a user keys a radio, the system selects an available channel, and directs the radios of all talk-group members to temporarily tune to that channel so that all members of the talk group can hear the call (that group's traffic).

9.2.2 Scope

Due to the aforementioned security and reliability mandate for public safety communications systems, public safety radio systems tend to be highly closed in nature. As such,

- Ideas such as sharing spectrum with other (non-public safety) entities aren't generally favorably received by the public safety user community since it is perceived to impact guaranteed assured communications
- Historically public safety users set a high bar that requires new technologies and/or algorithms to be proven to be reliable. The user community is dispersed, and new technologies and/or algorithms are often approached with caution by until proven in practice to be mature. Procedures for trials to evaluate such operational capability tend to be ad hoc, and may encounter delayed communication of trial results, resulting in slower adoption rates than might otherwise be the case.

- There are numerous expectations of public safety users about the control, look and feel of their radios, often established by prior use of many generations of legacy LMR equipment with a common look, feel, and operating controls. Given the need to operate equipment under potentially life-threatening conditions, changes to the look and feel of the radios can have significant operational considerations. User acceptance and training requirements are significant considerations in deployment of changes in equipment design and user interface
- Public safety agency policies, procedures, and systems, issues – even among neighboring areas, technology, operational procedures, and organizational structure tend to be disparate, often due to political reasons.

The bottom line to a public safety end user is the ability to be able to communicate, with very understandable voice quality, instantly, wherever and whenever he or she needs to. Public safety users are extremely pragmatic and approach technology change with caution, even reluctance, when new technology requires (or enables) significant changes in operational procedure.

9.2.3 Technology

Radio technologies influence every aspect of public safety systems, at the network/system level down through the finest level of detail on a radio's printed circuit board. The choice of technologies, processing algorithms, and network management techniques is critical for meeting the aforementioned rigorous demands of this market segment.

Every new public safety radio produced by the major radio manufacturers undergoes an extensive, comprehensive size, weight, performance, and cost (SWPC) analysis during its initial design assessing the benefits of all relevant new technologies available. Key inputs to all aspects of this tradeoff are customer requirements—both explicit as well as the implicit ones driven by the customer expectations and user prior experience as discussed earlier. Choosing technologies that are mature enough to meet the reliability demands of the industry yet not so mature that they will become obsolete during the projected radio lifetime is a delicate balancing act. The bottom line for incorporating any new technology into a public safety radio is that this technology results in a more favorable SWPC operating point than the technology that it is replacing.

Due to this tradeoff process, public safety radios have progressed in an evolutionary fashion to continually higher degrees of being software defined. If a new CR technique or technology provides an improved SWPC, it is expected that the evolution will continue, albeit slowly in a "baby-step" manner, into a technology base that incorporates more elaborate CR techniques.

9.2.4 Economics

As discussed previously, cost considerations are a key constraint in the SWPC tradeoffs for a public safety system. There are traditional cost boundaries that funding organizations (e.g., the government entities and taxpayers that fund public safety organizations) are accustomed to, and for users to exceed these boundaries, they must be able to clearly see, understand, and justify a favorable cost/benefit tradeoff. This economic impact also affects the rate of technology refresh over time. Due to the rigorous requirements associated with public safety radios, commercially available, high volume ASICs produced for cellular radios cannot be used, and the public safety radio market is small when compared to the commercial cell phone market. Thus, public safety has yet to benefit substantially from economies of scale cost reduction.

9.2.5 Politics

Public safety is a heavily regulated, with every radio model having to be certified by the FCC and every frequency used in a system having to be licensed. Such regulation is an important consideration in the attempt to introduce new CR technologies and techniques such as over the air radio waveform downloads into the regulatory framework.

As discussed previously, politics is a substantial driver on the direction taken by the public safety industry. For example, politics plays a large part in a jurisdiction receiving public funding for a new system, and conversely can quickly kill a radio project if a community's politics turns against it.

Cost and risk/maturity of the technologies employed in a system influence political considerations, since both can have a heavy influence on public opinion. For example, the latter can be a source of unfavorable press if the technologies happen to develop unforeseen performance "glitches" that will invariably be exploited for political advantage by opponents of the system. Such press can even lead to legal wrangling as the situation gets amplified into an unstable state. As noted above, political pressure in regard to funding also affects the rate of technology refresh over time where lifecycle expectations are often measured in decades. Conversely, introduction of new technology is sometimes expedited as a result of some political event, such as a natural disaster, terrorism, or an initiative arising in some part of government.

Politics also plays a role in cooperation between numerous, disparate, public safety agencies throughout an area. Each agency is usually associated with an independent political entity, and local funding is involved in fielding these systems; often to satisfy local needs first, and then to accommodate regional needs. Often the most economical solution is deployed.

Political considerations can even be a factor at the lowest level of system design. For example, locations of towers often create political controversy from the general public as well as environmental groups.

9.2.6 Structure

A public safety radio system typically consists of:

- The hand-held radios carried by public safety users, called portables. These are battery operated, typically with 3 to 5 watts power output.
- Vehicle-mounted radios, called mobiles. These run off the electrical system of the vehicle, and so are less constrained by size, weight, and power considerations.
- Radio base station sites, usually with 100 watt transmitters and antennas mounted on towers typically 150 to 400 feet high. They communicate to/from the mobiles and portables via an air interface.

- A network that ties together several base stations to facilitate wide area coverage and roaming and also typically includes data hosts, PSTN services, dispatch centers, other networks, and system administrative centers. The network is the backbone for information flow between the user radios (mobiles and portables) and external services.

Communications on a public safety radio system is usually either “one-to-many” via a land mobile trunked radio network (i.e., group calls), or direct one-to-one (or one-to-a few) without support of any networked resources (via repeater or direct links). This is in contrast to “one-to-one” cellular communications via commercial network (i.e., individual telephone call) traffic that dominates cellular phone systems. Since LMR users in a group tend to be distributed over large areas, LMR topology typically tends toward maximizing the area covered per frequency used on a group call to maximize network coverage efficiency with the minimal number of sites. Thus, high towers, high power, widely spaced sites are the norm for the group call oriented public safety system. This is in contrast to commercial cellular topology which is typically optimized for maximum frequency re-use within a geographical area to support the maximum number of individual calls; a network design constraint, as discussed below, requiring a much larger number of relatively lower-power sites.

9.3 Cellular Telephone

9.3.1 Purpose

A Cellular Telephone system is one in which customers are given a wireless handset with which to make full duplex telephone calls, exchange messages, and access data services. It is characterized by an infrastructure comprised of a large number of local cells operating at low power, with backhaul to a central mobile service center. This arrangement makes possible spectrum reuse, as the same frequency can be carrying a number of calls in adequately separated different parts of a geographic area.

Cellular systems traditionally attempt to provide wide coverage and high capacity. Applications are provided by both the service provider (e.g., Verizon) and by third parties (e.g., iPhone applications on AT&T). Some service providers focus on providing primarily low-cost local service (e.g., Cricket or MetroPCS) while and others provide nationwide or international service plans.

9.3.2 Scope

Cellular telephone networks are self sufficient systems that overlay the landline switched “plain old telephone service” (POTS). They are differentiated by their use of wireless technology for the “last mile”, permitting untethered use of terminals, with provision for terminal handoff between base stations when the mobile unit is in motion. They are interconnected with the switched network, permitting voice connection between wired and wireless telephones. Newer versions of these systems also have provision for data, enabling “smart” cell phones that are in reality small computer terminals with voice capability. Internet connections are also available to wireless terminals.

9.3.3 Technology

There are a wide variety of air interfaces used for cellular systems as service providers seek to continually improve profitability by increasing capacity, offering new services, and decreasing costs. Some of the currently deployed technologies (including trial deployments) include: GSM, EDGE, HSPA, IS-95, EVDO, WiMAX, and WiBro. Additional technologies are listed in Figure 18.

	Downlink		Uplink	
	Peak Network Speed	Peak Achievable User Rate	Peak Network Speed	Peak Achievable User Rate
EDGE (type 2 MS)	473.6 kbps		473.6 kbps	
EDGE (type 1 MS)	236.8 kbps	200 kbps	236.8 kbps	200 kbps
Evolved EDGE (type 1 MS)[36]	1184 kbps[37]		473.6 kbps[38]	
Evolved EDGE (type 2 MS)[39]	1894.4[40] kbps		947.2 kbps[41]	
UMTS WCDMA Rel'99	2.048 Mbps		768 kbps	
UMTS WCDMA Rel'99 (Practical Terminal)	384 kbps	350 kbps	384 kbps	350 kbps
HSDPA Initial Devices (2006)	1.8 Mbps	> 1 Mbps	384 kbps	350 kbps
HSDPA Current Devices[42]	3.6 Mbps	> 2 Mbps[43]	384 kbps	350 kbps
HSDPA Emerging Devices	7.2 Mbps	> 3 Mbps	384 kbps	350 kbps
HSDPA	14.4 Mbps		384 kbps	
HSPA[44] Initial Implementation	7.2 Mbps	> 4 Mbps	1.46 Mbps	1 Mbps
HSPA Future Implementation	7.2 Mbps		5.76 Mbps	
HSPA	14.4 Mbps		5.76 Mbps	
HSPA+ (2X2 MIMO, DL 16 QAM, UL 16 QAM)	28 Mbps		11.5 Mbps	

	Downlink		Uplink	
	Peak Network Speed	Peak Achievable User Rate	Peak Network Speed	Peak Achievable User Rate
HSPA+ (2X2 MIMO, DL 64 QAM, UL 16 QAM)	42 Mbps		11.5 Mbps	
LTE (2X2 MIMO)	173 Mbps		58 Mbps	
LTE (4X4 MIMO)	326 Mbps		86 Mbps	
CDMA2000 1XRTT	153 kbps	130 kbps	153 kbps	130 kbps
CDMA2000 1XRTT	307 kbps		307 kbps	
CDMA2000 EV-DO Rev 0	2.4 Mbps	> 1 Mbps	153 kbps	150 kbps
CDMA2000 EV-DO Rev A	3.1 Mbps	> 1.5 Mbps	1.8 Mbps	> 1 Mbps
CDMA2000 EV-DO Rev B (3 radio channels MHz)	9.3 Mbps		5.4 Mbps	
CDMA2000 EV-DO Rev B Theoretical (15 radio channels)	73.5 Mbps		27 Mbps	
Ultra Mobile Broadband (2X2 MIMO)	140 Mbps		34 Mbps	
Ultra Mobile Broadband (4X4 MIMO)	280 Mbps		68 Mbps	
802.16e WiMAX expected Wave 1 (10 MHz TDD DL/UL=3, 1X2 SIMO)	23 Mbps		4 Mbps	
802.16e WiMAX expected Wave 2 (10 MHz TDD, DL/UL=3, 2x2 MIMO)	46 Mbps		4 Mbps	
802.16m	TBD		TBD	

Figure 18. This is just a partial listing of cellular technologies. From: http://www.rysavy.com/Articles/2007_09_Rysavy_3GAmericas.pdf

While there are a wide variety of technologies, a few technologies are encountered more frequently, most notably GSM which retains a large worldwide presence due to the continued strong demand for voice services even as more advanced networks are deployed to support applications such as mobile broadband.

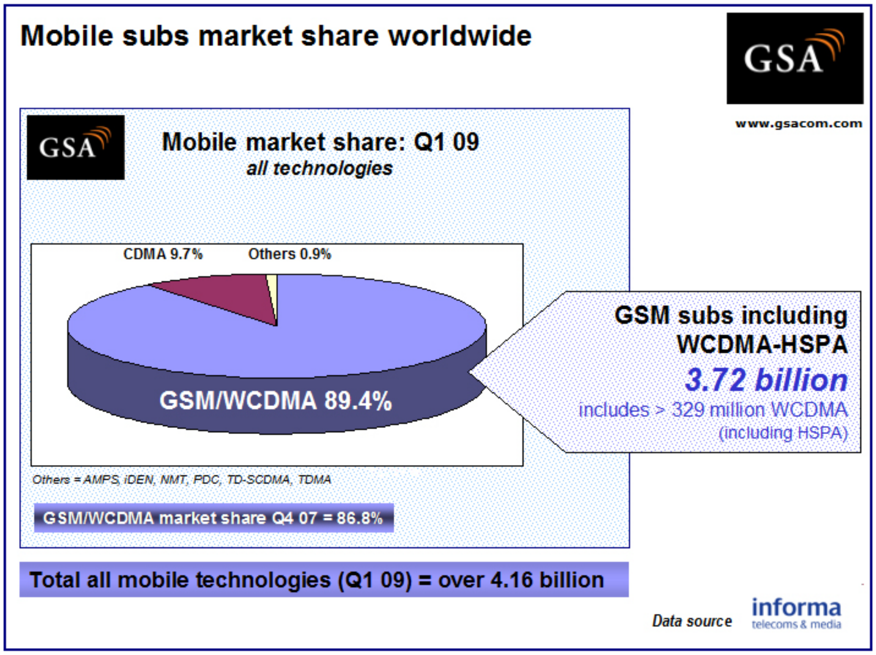

Figure 19. The GSM / 3GPP family of standards are the most popularly deployed networks. http://www.gsacom.com//downloads/charts/GSM_market_share_global.php4

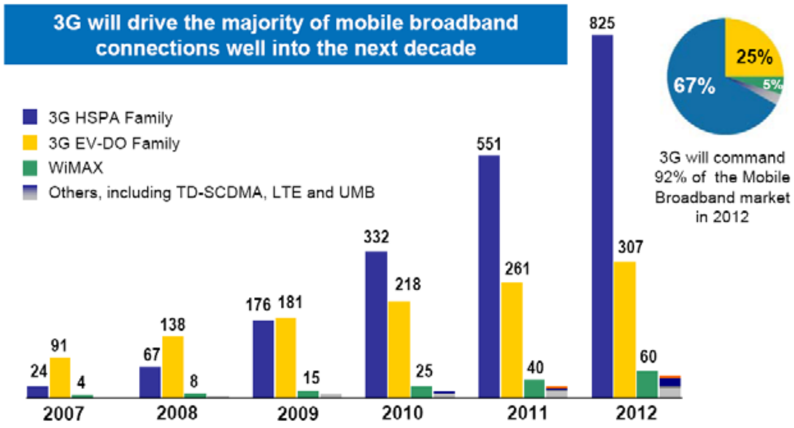

Figure 20. Mobile broadband services will continue to see a mix of cellular technologies. From: http://www.eng.chula.ac.th/files/AttachedFiles/Events/WirelessAcademicDays/3G_Broadband_and_Beyond_082108_Qualcomm.pdf

This mix of technologies has lead to user equipment that supports multiple modes and multiple bands.

9.3.4 Economics

Voice subscription services have traditionally been the primary revenue stream for cellular services with user equipment sold under cost as a loss-leader. However with the increasing deployment of high data rate networks, business models are evolving. This includes data subscription and ala carte services (e.g., apps and text messages) as well as application-centric sales where the network is hidden from the user. An example of the latter is Amazon's Kindle where users download books and other reading material directly to their device over cellular networks without ever signing a service agreement with a cellular service provider. A similar phenomenon happens with WiFi services on planes on the GoGo network (Aircell) where air-to-ground connectivity is provide via a network of EVDO base stations that most users are unaware of.

Figure 21. Aircell provides the backhaul for WiFi service on planes via a network of EVDO base stations (depicted as circles) on the ground. From http://www.aircell.com/index.php?option=com_content&task=view&id=312&Itemid=1

9.3.5 Politics

Cellular service providers purchase licenses for spectrum in specified regions in specified frequencies from government spectrum authorities. Traditionally, these licenses required service providers to implement certain networks (e.g., ChinaMobile was required to deploy TD-SCDMA in their 3G spectrum) or classes of networks (see the effort to classify WiMAX as 3G). Similarly, the recent 700 MHz Block D auction in the US placed requirements on the winner to support public safety communications, though no bid qualified. In general, these requirements are being relaxed to allow for easier migration of networks between technologies, though this is a slow process.

Cellular systems high demand for spectrum often brings service providers into contention with other wireless technology vendors when new spectrum is made available.

Because of the variations in license availability and networks, many operators enter into roaming agreements with one another, though this is more complicated for data roaming because of the variety of service packages. Sometimes a significant fraction of revenues an operator's revenues can come from providing coverage in areas too sparsely populated for other operators to cover directly (e.g., MidTex). Additionally, underused spectrum is occasionally released to other service providers on short or longer term bases.

9.3.6 Structure

Traditionally deployed as a hierarchical network with voice switched circuits, cellular systems have evolved to become:

- much flatter, without central control and with cooperative resource management
- IP based with 4G systems intended to even carry all voice over IP

Figure 22 depicts the network structure of an LTE (Long Term Enhancement – a 3GPP technology) network. Note that their enhanced node B (eNB) – the traditional base stations – can communicate directly with one another or with the packet core depending on the service and user being supported. This structure is growing more complicated as service operators allow femtocells to be deployed and allow users to move back and forth between cellular networks and WiFi networks. To simplify the deployment and maintenance of these networks, 3GPP and NGMN are standardizing a technology known as *Self-Organizing Networks* to automatically perform many of the deployment and maintenance tasks that were traditionally performed by humans.

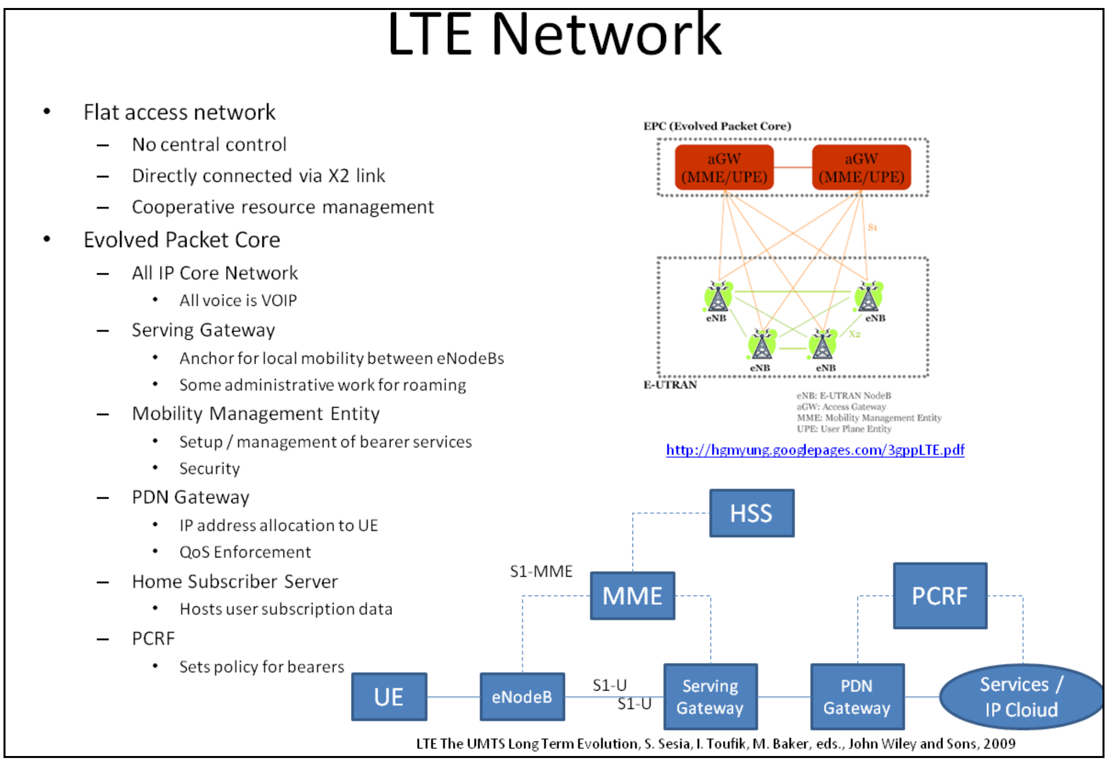

Figure 22. Major components of an LTE Network. From J. Neel, "Emerging Wireless Standards," VT Wireless Symposium, June 2009.

9.4 Television Broadcast

9.4.1 Purpose

Broadcast Television operates on one of a number of specific channels in a metropolitan area. They transmit continuously during operating hours. Programming may be originated locally, be provided by a network, or consist of previously recorded commercially available material. Their primary source of revenue is advertisements ("commercials"), which they intersperse with program material.

9.4.2 Scope

Television broadcasting concentrates on metropolitan areas where its signal can be received, but its programming is often carried by cable and satellite companies serving the same area. Some of the programming provided by networks is national or international in scope, but the content will be selected to be of interest to the local audience, and local commercials may be substituted for those supplied by the network.

9.4.3 Technology

Digital TV[24] format is now the standard, replacing analog TV signals broadcast in the past. The transition date varies by country; TV broadcast in the US has been completely digital since June 11, 2009. High powered transmitters transmit continuously. Digital stations have options about how their bandwidth is allocated; several low definition signals may be combined, and some sub-channels may be allocated to data transmission. Current high-definition technology delivers an excellent picture, and three-dimensional TV will soon be available.

9.4.4 Economics

Advertising is the primary source of revenue, and program material is the primary cost, along with the organization needed to sell ads produce local material, and operate station equipment. Many organizations that publish newspapers also own TV stations.

9.4.5 Politics

Broadcast Television stations are licensed by the FCC, and must justify their compliance with conditions of the license, such as public service programming at regular intervals.

9.4.6 Structure

As a system, broadcast television is simple. High speed digital circuits are used to bring in most program material, some of which is stored on magnetic devices for later transmission. Locally, a studio with cameras, editing, and control facilities is used for "live" programming. Remote cameras are carried on aircraft, or feed signals over microwave links from specially equipped

[24] See Wikipedia Article Digital Television: http://en.wikipedia.org/wiki/Digital_Television

trucks. Material for broadcast is fed from the control facility to a transmitter usually at an elevated location for maximum reception range.

9.5 Credit Card Transaction

9.5.1 Purpose

A plastic card, sized 85.60 x 53.98 mm, is the only essential physical manifestation of a huge information-based industry with nearly a trillion dollars of outstanding charges from 400 million cards in the US at a given point of time. The card is used in payment by a customer for goods and services received without exchange of money. Each day 500 million transactions are made with an average value of $66. Amount of the transaction makes its way to a monthly bill to the customer, while funds are advanced to the provider.

9.5.2 Scope

Financial institutions issue credit cards to their account holders according to procedures specified in their contracts with Credit Card Companies. Merchants contract with a financial institution to accept their credit card transactions. Credit Card Companies provide a clearing-house service whereby transactions from anywhere in the world find their way back to individual customer accounts. This system can be used for any kind of payment, so it interfaces with sales and marketing systems, point-of-sale transaction systems, and personal and commercial bank account systems.

9.5.3 Technology

Merchants and service providers can use the physical card or merely indication of codes embossed on its service to initiate a transaction. Transactions are transmitted through the internet from point of origination to the merchants back, through the clearing house, and on to the customer's bank. Transactions are generated by card readers or point-of-sale systems, and transmitted over the Internet in defined record formats.

Wireless technology currently plays a relatively minor role in Credit Card Systems. In some areas businesses such as restaurants bring a wireless terminal to the table to swipe the card, so it never leaves the customers' sight. In the future it is likely that smart phones or similar devices will enable wireless payment to vending machines, resulting with a charge to the Customer's Credit Card.

9.5.4 Economics

Credit Card systems are an example of economies of scale. Because of the very large number of transactions, the marginal cost per transaction for the financial institution is infinitesimal. The cost of data processing system development and equipment is substantial, but still very small on a per-transaction basis when amortized over the transaction volume of several years.

Sellers are charged a percentage fee of 1-3% of the transaction amount. Customers who do not pay their monthly statements in full are charged fees that may range as high as 25% of the remaining balance each month. Because of the high transaction volume, the resulting cash flow from these fees is substantial.

9.5.5 Politics

Because consumer financial transactions are involved in Credit Card systems, restrictions are imposed on the fee structure, and the right of banks to change conditions of card use.

9.5.6 Structure

A *Customer* is issued a credit card and given an account number by a *Card-Issuing Bank* (CIB). To make a purchase or enact a financial transaction, the Customer provides a *Merchant* with the credit card account number. The Merchant validates the account number and available credit balance with the *Acquiring Bank* (AB), and completes the transaction with a point of sale (POS) system.

At some point, the Merchant submits a number of completed transactions as a batch to AB. The Merchant's account is credited for the amount of transactions in the batch less transaction fees. AB submits the transaction to a *Credit Card Company* (CCC), and receives payment. CCC then debits CIB, and receives funds. CIB adds the transaction amount to the Customer's amount owed. Once a month CIB sends Customer a bill for the accumulated transactions, and receives payment from the Customer as a check or funds transfer from the Customer's checking account.

The entire system handles funds as data. Careful system design is required to ensure that funds are carefully accounted for at all times. Although computer systems can easily duplicate the bits that represent funds, accounting controls assure that account balances at each end are properly adjusted to reflect that the funds have been transferred.

9.6 Personal Bank Account

9.6.1 Purpose

Money is sometimes found in the form of cash, but most of an individual's funds are more likely to be in a bank account. That account is a means by which an individual can receive money, and expend it as part of a financial transaction.

There is no physical representation of those funds except in the form of records on computer system storage units. Although most individuals have bank accounts, the number of checks written has dropped dramatically with on-line banking. A large proportion of deposits are made by funds transfer, and many payments are also made electronically.

9.6.2 Scope

Bank Accounts are the means by which banks hold money. A *Personal Checking Account* is a type of account called a Demand Deposit Account by which a *Customer* can deposit funds to a *Commercial Bank* (CB) and make payments by withdrawing cash, writing checks, or authorizing funds transfers. CB interacts with customers, other financial institutions, and government agencies such as Federal Reserve Bank and Federal Deposit Insurance Corporation.

Another type of account is a *Savings Account.* The bank may require advance notice for a withdrawal, and pays interest on funds on deposit for a specific length of time.

9.6.3 Technology

Checking accounts are maintained by conventional data processing systems and their associated communications systems. Transactions are accomplished by Tellers using Teller Terminals, through Automated Teller Machines (ATMs), and by processing checks. Checks were formerly returned to the writer using Check Sorting Machines, but with current technology the paper check is scanned into the system, and the paper check retained by the bank that receives it. The check is then processed as data for transferring funds specified by the check face value. The check image is sent to CB where the Customer can view it.

9.6.4 Economics

Bank Accounts provide a means by which funds can be transferred very economically. Unit cost of a payment is infinitesimal when fully automated, as many are. If a physical check or cash payment is involved, then costs arise from the labor required to handle them.

The bank pays interest on checking accounts, and often levies fees for various services associated with other types of accounts.

9.6.5 Politics

Trust in currency is fundamental to any economic system more complicated than barter. That trust is based on belief in stability of the government backing the monetary system. As the institution that creates money and manages its logistics, banks operate in an environment that is inherently political.

Monetary policy, control of interest rates and the money supply, is an important tool for maintaining stability in the economy. Automated banking systems provide much of the data used by government organizations to perform the duties associated with implementation of monetary policy, and effective communication systems enable them to do so in near real time.

9.6.6 Structure

The fundamental structural elements of banking are the record of account balances and processing of financial transactions in their data processing systems. Deposits and funds transferred into individual accounts increase payments, checks, funds transferred out, and cash withdrawals reduce them. Bank systems depend on communication to access transactions taking place at bank stores and ATMs, and to communicate with other banks.

9.7 Materiel: Inventory Management

This section describes generic characteristics of Inventory Management systems.

9.7.1 Purpose

An inventory is a collection of physical items produced and stored as goods in a market, supply chain, or materiel system. The purpose of the inventory is to buffer variations in supply and demand in preparation for further processing, transfer to another inventory, or consumption.

Inventories have a variety of names, including raw materials, work in process, finished goods, wholesale, retail, spare parts, and others. The common thread in all of these different applications is receipt of physical items, their storage, and delivery in response to an order, sale, or requisition.

The Inventory Management system is an information surrogate for the physical items in stock. It tracks the physical inventory, and issues directives to store, move, further process, or ship out materiel. When items are received, a receipt to stock transaction increases the quantity on hand value in the item inventory record. When an item is sold or issued, a transaction reduces the inventory item balance.

There are two key measures of performance for an inventory system, and they are in direct conflict. One is level of service, the number of times that a request for a withdrawal finds the item out of stock. The other is carrying cost of inventory and risk of obsolescence. It costs money to put an item in inventory, so the carrying cost per unit time is an opportunity cost, representing other uses to which that money could be applied. Alternately, it is the interest to be paid on a loan to pay for purchase cost of the item. A higher service level is desirable, as is a low carrying cost. Both measures are directly related to the average quantity on hand; improving one makes the other worse.

The underlying concept of Inventory is static: a stock of goods whose sole benefit is one of utility, the ability to deliver items quickly.

9.7.2 Scope

Inventory Management systems are components of larger institutional systems, where they provide both physical storage of items and information to control the inventory. They are interconnected to Order Management systems for item shipping and delivery, and to production systems where value is added. Inventory Management Systems also interface with accounting systems to provide inventory evaluations, and other application-specific systems, such as point-of-sale in retail.

9.7.3 Technology

Inventory management systems are part of the data processing repertoire of an organization, where inventory records are maintained. They make use of two types of specialized technologies, item identification, such as barcodes and RFID chips, and interfacing with automated materials handling equipment. RF facilities are useful in communication throughout large storage facilities, such as warehouses.

9.7.4 Economics

An inventory is an asset, and carried on the balance sheet as long as it is in inventory. When shipped as part of an order, the inventory value is relieved of the asset value, which becomes part of cost of goods sold. Inventory management involves balancing inventory cost with cost of a stock-out. A typical system will have reorder points set for each item; when inventory on-hand drops below the reorder point, an order is placed for an economic order quantity derived from projected demand, and supply parameters, such as quantity discount, delivery time, or economic production run size.

9.7.5 Politics

Inventory Management systems do not have inherent political considerations, but if the items stored are sensitive, or if the application has large-scale economic implications, political considerations may arise.

9.7.6 Structure

The physical characteristics of inventories include arrival of items at a physical location, their storage, and removal in response to an order. The associated information system is a surrogate for the physical system and provides information needed to manage it. Transactions for items received add to the inventory level, those for items shipped, sold, or issued reduce the quantity on hand. The less frequent complementary transactions, respectively removal from inventory and item returns, must also be accommodated, and accurately reverse all of the changes resulting from the original transaction.

Provision is made for adding new items to the inventory, and for deleting item types removed from the system. A central master record is maintained for each item, with provision for a unique part number or product code, variety of descriptive fields, and fields to track usage and level of inventory on hand.

9.8 Materiel: Order Management

This section describes generic characteristics of systems that reflect customer demand, and satisfy that demand.

9.8.1 Purpose

In a Materiel system, an Order Request is information sent to a supplier by a client requesting movement of physical items. Order Fulfillment is the process of accomplishing the requested movement. In common terminology, these are both the request and the assembled package of goods transferred are referred to as “an order.”

An order, then, can be considered as removal of items from an inventory to be consumed, processed, or deposited into another inventory. An order is goods in motion; an inventory is goods in storage. So these two concepts are closely related.

Some organizations manufacture or buy and sell physical products as a means to generate revenue. An Order Entry system accepts customer orders, and places a demand on inventory. If the item is found to be available in the storage facility, provisions are made to deliver it to the customer. If the item is not available, an out-of-stock procedure is activated.

In other applications the request may be referred to using names such requisition, bill of materials, or retail sale. The resulting physical delivery may be called an issue, parts kit, merchandise, or delivery.

The underlying concept of Order Management is dynamic, expressing a request for items, arranging physical delivery, and modifying inventory. The order is transitory, and becomes part of the historical record when fulfilled.

9.8.2 Scope

Order Management systems are components of larger institutional systems, where they provide both means to communicate requests for items and execute their physical delivery. They are interconnected to Inventory Management systems for item storage, and to production systems where value is added. Order Management systems also interface with accounting systems to provide revenue data.

9.8.3 Technology

Order Management systems are part of the data processing repertoire of an organization, where orders are accepted, shipment instructions generated, and records maintained of deliveries per unit time. Because communications are an inherent part of Order Management, a variety of communication technologies may be employed.

9.8.4 Economics

Profit results from sales after reduction by cost of goods sold, and overhead such as selling and administration. An effective commercial order entry system stimulates customer good will, assists the sales force, provides input for inventory management, and forecasts shipment volume. In non-commercial systems an effective order management functions at lower cost and better levels of service.

9.8.5 Politics

Order management systems do not have inherent political characteristics. For specific applications, such as restricted items, there may be legal requirements that constrain such items as who can order, order size, or restrictions on ship-to address.

9.8.6 Structure

The physical activities of an Order Management system typically involve movement of items from one place to another in response to customer orders. The information component of an Order Management system includes facilities to accept customer orders, check inventory, and issue shipping papers and invoices. Static item information is retrieved from the item master record.

9.9 Material: Greencastle, An Example

This section is a description of the system used by Corning Glass Works for management of its Pyrex brand Consumer Products system in the later decades of the twentieth century. It is provided as an example of the framework to describe a specific system described in general by the preceding Material sections.

9.9.1 Purpose

Corning Glass Works was a major supplier of glass cooking and eating utensils, such as bowls, pie plates and coffee pots. The product line consisted of several hundred line items that were sold to wholesalers throughout the country and Canada.

Products were made at a number of factories throughout the Eastern United States, where glass was melted, and product production runs of several weeks took place. The material was shipped by railroad to a large warehouse in Greencastle, PA., where it was packaged in display boxes, palletized, and put in stock.

Customer orders were processed each night and transmitted to the warehouse. Orders were assembled in staging areas, and loaded into boxcars. At day's end, the railroad took the loaded cars, and spotted empties at the loading doors.

At that time a system that delivered product overnight in trainload quantities was considered quite advanced.

9.9.2 Scope

The system interacted with a number of other systems, including manufacturing scheduling, general ledger accounting, and sales management. It was restricted to the Consumer Products Division, and only to their high-volume product lines and established customers.

9.9.3 Technology

The Corning Data Processing Department had been based on punch-card systems and IBM electro-mechanical equipment for some time, and had just started a transition to the RCA 301, a system using magnetic tape for storage. An advantage of magnetic tape is that records can be any desired length, adding considerable system design options over the constraints of 80 column cards. IBM 1130 computers were used at Greencastle, primarily for printing.

Communication from Corning to Greencastle was at slow data rates by either punched cards or paper tape. Printed documents were printed with high-speed line printers attached to computers.

9.9.4 Economics

Knowing that inventories could be replenished within a few days time meant wholesalers could operate with lower inventories.

9.9.5 Politics

The primary political influences were internal to Corning, where advocates of the system had to overcome concern about equipment cost and the substantial monthly equipment rental. Some managers in other divisions were concerned about diversion of system design resources from projects that they wanted for their organizations. Top management, however, felt that it was important to keep up with the emerging technology of computers and data processing, so they were supportive, and authorized the project to continue.

9.9.6 Structure

Salesmen in the field took customer orders, and phoned them in to an order entry unit in Corning, NY, where they were entered into punched cards. Orders were accepted up to a specified deadline, after which all the cards went into a Consumer Products Order Entry run at a scheduled time each day.

9.10 Air Traffic Control

9.10.1 Purpose

Air Traffic Control (ATC) is a system critical to the safe operation of the aviation industry. The purpose of ATC is to maintain safe distances, or separation, between aircraft while expediting the overall flow of air traffic. This is accomplished by assigning altitudes and routes to aircraft flying under Instrument Flight Rules (IFR). IFR replaces “see and be seen” with assigned slots that maintain separation from other aircraft.

Since the days of radio ranges in the nineteen thirties, air traffic control has lagged the state of the art of aerial navigation by decades. It still relies on sixty year old technologies such as Visual Omni Range (VOR) and Radar. Use of fixed routes wastes a vast amount of airspace, and terminal congestion disrupts the whole system when marginal weather occurs.

With precision GPS position information and very effective collision avoidance systems, there is no technical reason for the present dependence on manual system control. But in spite of expenditures of billions of dollars, regulators have been unable to mount an effective Free Flight air traffic control system, which would allow individual aircraft to take the shortest route saving time and energy. The air traffic control system could be greatly aided by many of the aspects of cognitive radios and self-organizing networks enabling aircraft radios to adapt to new airspaces and relay necessary information to air traffic computers to ensure flow control and safety.

This System Framework focuses on the U.S., but due to extensive standardization, systems around the world are very similar in operation.

9.10.2 Scope

ATC applies to all aircraft flying under Instrument Flight Rules (IFR). The intention of IFR is to provide adequate separation so that flights can proceed under conditions where visual (see, and be seen) operation is ineffective. ATC is a component of the Aviation Industry, and interfaces with the Airline Passenger business, Air Freight, Private Aviation, and Government Flight Operations, including the Military.

There are four entities that interact to support flight operations:

- Government agencies:
- Aircraft and their crews
- Aircraft Operators
- Airports

9.10.2.1 Government agencies

The primary agency responsible for control of flight operations is ATC. It is part of the Federal Aviation Administration, which promulgates policy in addition to its operational responsibilities. ATC is responsible for ground radar, navigational aids, communication links to planes, and Traffic Control Centers and Controllers. Other agencies involved are NWS for weather forecasts; FCC and NTIA for spectrum for aeronautical radio communication.

One primary element of the Air Traffic Control system is a ground based radar tracking system and associated controllers and communications facilities to communicate with aircraft. The second is aircraft and pilots following flight plans. The purpose of the ground-based radar tracking system is to provide aircraft position information to control personnel. The layout is based on geography with the continental United States broken up into 21 zones, or centers, each of which is further divided into a number of sectors. Contained in each zone is an Air Route Traffic Control Center (ARTCC) that controls traffic for all sectors within the zone. Also contained in each zone is at least one area about 50 miles in diameter called the Terminal Radar Approach Control (TRACON) airspace that may contain one or more airports; there are nearly 600 TRACON facilities in the US. Each major airport has an Air Traffic Control Tower (ATCT) and its own 10-mile diameter airspace within the TRACON. Overall there is >90% radar coverage of the airspace. The system, in conjunction with the associated air traffic controllers, is managed by the Federal Aviation Administration (FAA).

Figure 23. U.S. ATC Zone Map[25]

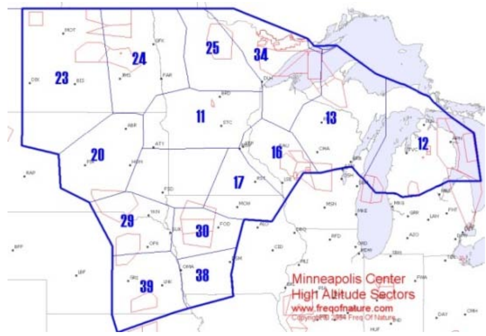

Figure 24. ZMP Zone Sector Map [26]

National Weather Service (NWS) provides en-route and terminal weather forecasts.

Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA) are responsible for spectrum allocation and rules for its use.

9.10.2.2 Aircraft and Aircrews

The other primary element of the system is the aircraft and pilots. There are typically 2 or 3 VHF transceivers aboard each plane that are used strictly for voice communication with the ground based ATC, and there is a directional transponder that transmits the aircrafts speed, heading, and altitude to secondary radars within the ATC radar tracking system. In addition, there is a teletype system for the communication of flight related information. The other radio equipment installed on board is used primarily for navigation purposes.

Cognitive radios will provide flexibility to shift between different modes of radios VHF (VDLM2, VDLM4), UHF (UAT), VOR, DME and others not yet identified. It will take years (~15?) to implement a new system due to the complex overlay of different systems and the role of international agreements. With proper safe guards put in place to ensure public safety, this complex design of system of systems lends its self well to the flexibility of cognitive radios.

9.10.2.3 Operators

Operators are the organizations that operate aircraft to support their goals objectives. They include Airlines that procure aircraft, establish schedules, and market flight-seats; private aircraft owners; Military Armed Services, and other Government agencies. Their interface with ATC involves organizing and optimizing the load placed on airspace, spectrum, and control capacity.

[25] http://images.google.com/imgres?imgurl=http://pilot2b.com/images/6/2/5/6/8/197293-186526/Tfrmap%255B3%255D.jpg&imgrefurl=http://pilot2b.com/2009/10/15/20091015-ndash-visit-of-an-artcc-ndash-part-1.aspx&usg=__2kuDyV7NHuYOwT9lNvgIU6IlADg=&h=452&w=640&sz=74&hl=en&start=15&sig2=S19TCoTFqrRyACg6Vt6Gsg&um=1&itbs=1&tbnid=pPTUIhOdgSPjaM:&tbnh=97&tbnw=137&prev=/images%3Fq%3Dartcc%2Bzone%2Bmap%26um%3D1%26hl%3Den%26safe%3Dvss%26sa%3DN%26ndsp%3D20%26tbs%3Disch:1&ei=vLezS4abAoLv-QaZ2OmeAw

[26] ibid

9.10.2.4 Airports

Airports are facilities that provide take-off and landing runways and time slots. They also provide facilities for loading aircraft, refueling, emergency services, and maintenance. Aircraft launching and recovery operations are susceptible to weather conditions, availability of ramp facilities, taxiway congestion, and peak hour runway availability. All of these elements require close coordination with ATC.

9.10.3 Technology

The primary element of flight operations is precise knowledge of aircraft position and altitude. Based on that information and the approved flight plan, ATC provides control to ensure safe and expeditious flight.

The system gathers information on aircraft location though the radar system and the transponders on the planes. The amount of information transmitted via the transponders is relatively small and consists of the aircraft identification, heading, speed and altitude. Actual control and coordination of the aircraft is accomplished mainly by voice communication between the controllers and pilots.

The primary radio spectrum used is in the VHF band, between 108 – 137 MHz, as established by the Federal Communications Commission (FCC). The lower portion of the band is reserved for radio navigation while the upper portion, 117.975 – 137.000 MHz, is reserved for mobile uses, not all of which is for ATC. The radios utilize Amplitude Modulation (AM) with 25 kHz channel spacing in the U.S., although in some parts of the world 3 data-link sub-bands of 8.33 kHz are required.

The overall concept of ATC has not changed in the last 75 years and consists of ground-based controllers tracking plane positions and then radioing commands to the pilots of the aircraft. The other thing that has not changed much is the amount of time required to install new technology into the system; about 10 – 20 years, actually it a little longer than it was 75 years ago. In today's environment of rapidly changing technology, there is a virtual guarantee that any new system that requires 10 – 20 years to deploy will be outdated by the time it becomes operational.

Cognitive radios will provide flexibility to shift between different modes of radios VHF (VDLM2, VDLM4), UHF (UAT), VOR, DME and others not yet identified. It will take years (~15?) to implement a new system due to the complex overlay of different systems and the role of international agreements. With proper safe guards put in place to ensure public safety, this complex design of system of systems lends its self well to the flexibility of cognitive radios.

Cognitive radios will provide flexibility to shift between different modes of radios VHF (VDLM2, VDLM4), UHF (UAT), VOR, DME and others not yet identified. It will take years (~15) to implement a new system due to the complex overlay of different systems and the role of international agreements. With proper safe guards put in place to ensure public safety (i.e. prevention of vehicle state information being disabled or intentionally sending incorrect information), this complex design of system of systems lends its self well to the flexibility of cognitive radios.

9.10.4 Economics

Approximate economic impact:

- Global Air Travel Revenues: $500B / year27
- Cost of U.S. flight delays: $15B / year28
- U.S. ATC budget: $13B / year29
- Cost of a single airplane crash: $800M? 30

The tracking system and controllers are mandated and funded by the Federal government and ultimately taxpayers. The budget of the system is subject to the normal difficulties of governmental budget constraints and the ins and outs of the parties that control the legislative braches of government. Specific aircraft ATC requirements are mandated by the FAA and FCC, funded by the airlines and ultimately paid for by the passengers of the airlines. The implementation of a cognitively based Free Flight System would result in shorter flight times meaning better aircraft utilization as well as fuel savings.

9.10.5 Politics

Virtually every part of the ATC system is regulated. The system itself is the responsibility of the Federal Aviation Administration (FAA). Controllers are licensed to varying degrees depending on their qualifications and job functions, the only Controllers licensed to use visual information are the Local and Ground Controllers at the airports with the decisions of all others relying solely on radar / computer information and pilot communications. Pilots are also licensed by the FAA with specific aircraft type endorsements. The ATC stations and aircraft are licensed by the FCC, as are Pilots and Controllers.

The system is under the control of the FAA and FCC. The implications of this are:

- The heads of both Agencies are political appointees as are many of those working directly under them.
- The budget is determined by Congress, which is subject to the ups and downs of political priorities.
- The systems manufacturers are largely defense contractors with deeply entrenched lobbyists reaching out to politicians who generally have an interest in seeing their districts get the funds.
- The controllers are unionized with contracts that are approved at a local level.
- The majority of non-appointees are life long government employees so that turn over at the planning levels is limited.

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[27] "IATA Cuts 2010 Loss Forecast in Half - Strong Start for 2010", International Air Transport Association, March 11, 2010.
[28] "DELAYED: The Soaring Toll", Del Quentin Wilber, Washington Post, January 27, 2008.
[29] "U.S. Department of Transportation Fiscal Year 2009 Budget in Brief: FEDERAL AVIATION ADMINISTRATION", Air Traffic Organization + Safety & Operations,
[30] "Insurers face huge payout over Air France Atlantic crash", Andrew Frye, Business Day, June 11, 2009.

- The common public generally considers any accident or loss of life incident unacceptable.
- Fear of failure and blame avoidance have dominated air traffic control policy for many years.
- Another significant consideration is that while the ATC is tasked with the safety of all aircraft, the responsibility of a single aircraft is ultimately the responsibility of the pilot.

9.10.6 Structure

The current normal sequence of events is that the pilot files a flight plan with the tower at the departure airport that includes the destination and desired route and altitude. This plan is approved and a flight progress slip is generated in the ATC system that follows the flight. A Ground Controller gives the aircraft clearance to push back from the gate and the taxiway route to follow to the departure runway and hands off the plane and flight slip to the Local Controller. The Local Controller then clears the plane for take-off and hands off the plane and flight slip to the Departure Controller. The Departure Controller then directs the plane until it reaches its cruising altitude where the plane is then handed off to the En route Radar Controller in that sector. As the flight progresses it is sequentially handed off to other sector En Route Radar Controllers until it is within range of the arrival TRACON. At this point, the Approach Controller takes over and directs the plane into the airport airspace and hands-off to the Local Controller who gives the final clearance to land. Once on the runway, the Ground Controller takes over and coordinates movement on the taxiway to the aircraft's gate.

With use of cognitive radios, air space controllers may allow Free Flight privileges within controlled air spaces to hasten the adoption of the technology. For example a flight leaving from JFK to CLE flies through one of the most traveled corridors in the world, after leaving restricted terminal airspace a cognitively equipped air plane could choose a different route depending on travel time, prevailing winds, etc., all the while sending status updates via whatever communications system there is available at the time (a cell phone tower, air cell tower, Inmarsat satellite, etc.). This state information and ETA would allow scheduling at the arriving airport while minimizing congestion.

Another potential use of cognitive technology is formation of ad hoc networks between aircraft in flight. With all aircraft publishing flight information, each of them can maintain a mapping of traffic in nearby airspace. Each aircraft can then optimize its flight pattern, and optimize its route of flight while notifying other aircraft (and ATC) of its intentions.