THE ROLE OF A METALANGUAGE IN THE CONTEXT OF COGNITIVE RADIO LIFECYCLE SUPPORT

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ABSTRACT

The full value of Cognitive Radios will be achieved when they can autonomously fully meet the goals and objectives of all roles in the wireless value chain across the entire life cycle. Value chain participants include: Network Operators, Equipment Vendors, Software Vendors, Semiconductor Vendors, Component Vendors, Regulators and End Users. In order to achieve this, it is necessary to have a language that provides an interface to each of these groups on one side and to the radio systems (hardware and software) on the other side that supports such autonomous functionality. This language, called a Metalanguage, contains information about hardware / software functionality / configuration, Air Interface Standards (AIS's), information being exchanged, and end users. This paper focuses on scenarios that will result from the use of such a language.

1. INTRODUCTION & BACKGROUND

Wireless systems are increasingly becoming more heterogeneous and configurable. The design, deployment and management of these systems entail several tasks that require communication and interaction between components in the system, at varying levels of detail. To enable such interaction, it is both useful and important to have a Metalanguage that enables a uniform way to describe and access attributes of various system components, Air Interface Standards (AIS's), types of information being carried, and characteristics of the end users. In order to be accepted by the community, such a Metalanguage has to be able to interface with existing standards that are domain specific, pertaining to hardware, software, mechanical, biometric, security subsystems, etc. Further, the design of such a Metalanguage must be cognizant of the needs of all of the key participants in the ecosystem, including wireless carriers and enterprises, system vendors, semiconductor / component suppliers, regulatory agencies, and end users. It is important that this be done in a way that is not perceived as being biased by any of the various players.

This paper provides a brief background including references to earlier work and then focuses on explicating the value of a Metalanguage through several scenarios. The scenarios are purposely oversimplified and the AIS's used are merely illustrative. The intent is to make it easy for the reader to understand the basic structure. Actual implementation will take a much greater degree of detail, a very large pallet of AIS's and a wide variety of very different situations. The scenarios will also change substantially as they are implemented in different geographic regions. The reason that there can be a single Global standard Metalanguage is that all this great variety can be abstracted into a bounded language. The language, of course, will have to change over time as technology evolves. To that end, a mechanism that will allow the industry to grow and develop the Metalanguage is needed.

The motivation behind this work is the desire to create a single global standard Metalanguage that meets all the various proprietary, market segment, and geopolitical concerns of the industry. Only with such a global standard Metalanguage, can the full promise of Cognitive Radio be achieved. Some of the drivers, functionality and benefits that can be derived from the Metalanguage are described in "Perspectives On A Metalanguage For Configurable Wireless Systems".

2. DEFINITIONS:

In logic and linguistics, a **metalanguage** is a way of providing information about information. Here, we use the term Metalanguage to mean a system for describing the current configuration of a radio and therefore its current functionality, its potential configuration / functionality; the characteristics of current and potential waveforms and Air Interface Standards (AIS's), the type of information being handled and the end users invlolved.

In computer science, an ontology is a data model that represents a domain and is used to reason about the objects in that domain and the relations between them. Such reasoning is likely to play a role in the use of some aspects of the Metalanguage. Therefore, one aspect of the Metalanguage can be thought of as an ontology.

In addition to content, the metalanguage must provide a protocol for exchanging that content and resolving conflicts in input data and desired outcomes that result from that exchange.

The basic architecture behind the metalanguage is described in the SDR Forum "TR2.1" and the SDR Forum "Commercial Handset Guidelines". It is essentially the way that Switchers communicate. To this basic architecture are added two new components. The first is further detail inside the Switcher and the second is the addition of a Control Point.

The Switcher consists of several elements. There are interfaces to the network and to the radio. Between these two interfaces are procedural and non procedural logic. The procedural logic is supported by a database and focuses on fixed functionality, low volatility aspects. The non procedural section contains an inference engine supported by an ontology and focuses on complex variable functionality with high volatility.

The Control Point is similar to the switcher in internal structure. It can move around in the network. It can be broken into several pieces that are in different parts of the network. It keeps a “global” perspective within its span of control. It focuses on those aspects which, by their very nature, are hierarchical in nature.

3. PUBLIC SAFETY SCENARIO

The problems of first responders to disasters have received much attention recently. The first scenario we will consider here revolves around these problems. The elements involved in this scenario will be seen to be the same elements that occur in the other scenarios. These basic elements and their interaction define the Metalanguage.

In this scenario there is a fire at a chemical plant in an urban environment. We will be concerned with three first responders and their radios. The three are an incident Leader, a Fire Person and a medical professional (Medic for short).

The Leader arrives with a portable radio which can be configured as a CDMA 1X RTT cellular, WiFI (2.4 GHz), or WiMax (5GHz) radio.

The Fire Person arrives with a specialized fire network radio that can be configured to support CDMA 1X RTT cellular, WiFi (2.4 GHz), WiMax (5GHz) if correct S/W is downloaded.

The Medic arrives with a specialized fire network radio that can be configured to support CDMA 1X RTT cellular, WiFi (2.4 GHz), WiMax (5GHz) if correct S/W is downloaded.

The Leader arrives first. His radio “sniffs” the RF environment and determines that there is a CDMA 1XRTT basestation in the area with some bandwidth available and a functioning unsecured WiFi access point with connectivity to the Internet. The leader’s radio deduces that the Cellular Basestation is likely to provide the most reliable connectivity. The Leader’s radio registers with the basestation. The leader’s radio informs the basestation that it is a Leader radio, checks that there is no other leader present and assumes that portion of the Control Point appropriate to an incident Leader.

The Fire Person arrives and seeks connectivity with a Leader. His radio first seeks a leader on the specialized Fire AIS. Finding none, the radio starts downloading other AIS’s over the Fire AIS and starts sniffing for other AIS’s. The radio detects a CDMA basestation pilot, registers with the CDMA basestation and requests (using Meta Language) connection to a leader. The fireman’s radio connects with the Leader’s radio identifying itself (current configuration and potential configurations), its user, and requests instructions via an async data session. The Leader’s radio deduces that the Fire Person’s radio will likely need detailed maps / plans of the site, lists of dangerous chemicals likely to be on site and that the Leader will likely need streaming video from the close vicinity of the fire and that the leader and the Fire person will require a voice channel initially. The Leader’s radio determines that the best use of available spectrum given that there are likely to be a large number of responders is for the Fire Person’s radio to initially use the 5GHz WiMax band configured for streaming video, async data and VOIP. It instructs the Fire Person’s radio over CDMA 1XRTT channel to switch to 5GHz WiMax.

The Fire person’s radio determines that given the impending arrival of a large number of responders, the best way to obtain the required WiMax S/W is to switch to the previously detected WiFi access point and download it that way. Using its Metlanguage definition of its existing hardware and S/W platform, it finds the appropriate software on the Internet to allow it to reliably operate on 5GHz WiMax and downloads it. The Fireman’s radio checks the downloaded S/W modules against its Meta Language configuration description. If the Fireman’s radio determines that the module is will operate correctly, not cause any problems on the local radio and will not emit any spurious emissions, the radio loads it. It then initiates a WiMax VOIP and streaming video session with the Leader. While this is happening, the Fire person’s radio is downloading site maps / plans and lists of likely dangerous chemicals via the specialized fire AIS and supporting infrastructure.

As soon as the Leader’s radio detects that it is in VOIP / streaming video session with the Fire Person, The leader and the Fire Person discuss the best direction / means to approach the fire from. The Fire Person approaches the fire. The leader observes the streaming video.

The Medic arrives on the incident scene. The Medic's radio seeks connectivity with a Leader. His radio first seeks a leader on the specialized Medic AIS. Finding none, the radio starts downloading other AIS's over the Medic AIS and starts sniffing for other AIS's. The radio detects a CDMA basestation pilot, registers with the CDMA basestation and requests (using Metalanguage) connection to a leader. The Medic's radio connects with the Leader's radio identifying itself (current configuration and potential configurations), its user, and requests instructions via an async data session. The Leader's radio deduces that the Medic's radio will likely need detailed maps / plans of the site, lists of dangerous chemicals likely to be on site and that the Leader will likely need async data to direct the Medic to injured people. The Leader's radio determines that the best use of available spectrum given that there are likely to be a large number of responders is for the Medic's radio to initially use the WiFi band configured for async data and VOIP. It instructs the Fire Person's radio over CDMA 1XRTT channel to switch to 2.4GHz WiFi.

The Fire person's radio determines that given the impending arrival of a large number of responders, the best way to obtain the required WiFi S/W is to switch to the specialized Medic AIS and download it that way. Using its Metlanguage definition of its existing hardware and S/W platform, it finds the appropriate software on the Medic infrastructure to allow it to reliably operate on 2.4GHz WiFi and downloads it. The Medic's radio checks the downloaded S/W modules against its Metalanguage configuration description. If the Medic's radio determines that the module will operate correctly, not cause any problems on the local radio and will not emit any spurious emissions, the radio loads it. It then initiates a WiMax VOIP and streaming video session with the Leader. While this is happening, the Medic's radio is downloading site maps / plans and lists of likely dangerous chemicals via the CDMA 1XRTT AIS from the Fireman's radio.

The Leader's radio seeing this pattern of usage, instructs the CDMA 1XRTT basestation to cache the maps / plans and lists of dangerous chemicals and deliver them to all Firemen and Medic's who arrive at the incident. The Medic's radio sends the list of dangerous chemicals over it specialized Medic AIS to its infrastructure requesting precautions and intial treatment for each.

As soon as the Leader's radio detects that it is in async and VOIP session with the Medic, the leader and the Leader tells the Medic he will send directions to injured people and any available info about their injuries via the async data channel and then disconnects from voice contact. Both radios shut down the VOIP session.

As more Fire people and Medic's arrive, control may be distributed with a Fire Leader and a Medic Leader. At the same time, people with different roles will begin arriving. Crowd control, air traffic control, etc. may become involved. With a little imagination, the reader can see how these intelligent radios with a metalanguage describing what the capabilities of the radios are, what the characteristics of their users are and the type and flow of information is can provide efficient communication. Further complexity can be introduced by allowing radios to move into unoccupied spectrum allocated to other users.

4. COMMERCIAL SCENARIO

Many cellular network operators, metropolitan areas and ISP's are deploying WiFi mesh networks. Many of them anticipate upgrading a portion or all of their networks to WiMax. In such a case we can consider a scenario using the same three AIS's as above (1XRTT, 2.4 GHz WiFi, 5 GHz WiMax). There are similar scenarios for load balancing at congested locations. For example when a major sports figure breaks a significant record at a sports stadium and there are voice only phones, phones with still cameras, and phones with streaming video cameras and 100,000 of them all want to communicate at the same time. Load balancing might also involve moving into unoccupied spectrum assigned to another primary user by the governing regulatory body.

Instead of going through the whole of each of these scenarios, we will focus here on the differences between these Commercial Scenarios and the Public Safety one

In each of these the Control Point is in network operator's infrastructure. It may move around within that infrastructure, but it never moves out of it. The number and variety of hardware / software platforms in the field is much greater and therefore the complexity of matching the correct S/W download to the correct platform becomes more difficult, while the potential damage to the network of a mismatch becomes much higher.

In the network upgrade scenario the time constraint is greatly relaxed. In the load balancing scenario, the time constraint can be much greater.

Cost is an important issue in commercial systems. There are two cost components that tend to dominate in these scenarios. One is the cost associated with human intervention. When automated systems break down, network operators typically fall back on customer service personnel. This is costly and therefore to be avoided. The second is the impact of failure to meet QOS expectations on the consumers part. Failure here can lead not only to directly lost customers, but also indirectly lost customers through degraded reputation.

Although, not yet much in evidence, there is another intriguing potential commercial scenario. This is when the Control Point moves to the user. Here, the end user instructs the radio in terms such as cost, time, latency, security, privacy, etc. and lets the radio figure out the best way to meet the end users desire. Although, current business models make this difficult, there are those who suggest that the industry will be forced in this direction.

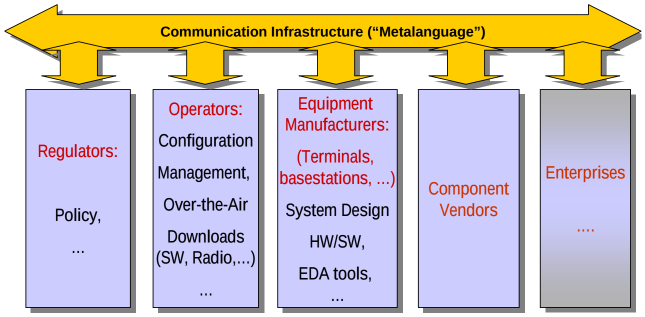
5. MILITARY SCENARIO

Military scenarios have many of the same properties as public safety and Commercial. In preparation for a mission, they share many of the characteristics of commercial scenarios. In execution of missions, they share many of the characteristics of Public Safety scenarios.

6. CONCLUSION

We have briefly overviewed the architecture underlying a Metalanguage that enables cognitive radios. We have examined how such a Metalanguage might function in some oversimplified scenarios. The next step is to build some example implementations of the Metalanguage in Switchers. The Commercial Working Group within the SDR Forum is in the process of doing so. The Working Group invites all who are interested to participate.

The authors' objective of is to create an open global standard Metalanguage describing device configuration / functionality, AIS / Waveform configuration functionality, and critical end user characteristics that will enable the wireless industry to deliver the full promise of Cognitive Radio.



7. REPRESENTATIVE DIMENSIONS

A metalanguage that supports the configuration and reconfiguration of agile terminals must satisfy certain requirements, starting from the local management reconfiguration procedures. These include, for example: monitoring and discovering the capabilities, status and offers of the networks in a certain area; configuration discovery; reconfiguration action selection and negotiation in order to select appropriate reconfiguration; general supporting procedures, namely, software download and installation. These are considered and discussed at a high level in the Commercial Handset Guidelines Document recently published by the Software Defined Radio Forum.

Other related work is currently underway in E2R, WWRF, OMA, JCP and elsewhere.

8. DIRECTIONS TO A SOLUTION

Given the observations above, we suggest a three-pronged approach to build upon the existing efforts. This consists of the development of a standardized metalanguage, an illustrative commercial SDR architecture, and an SDR technology projection that provides usage scenarios.

A metalanguage in this context provides a consistent way of describing the capability and various performance attributes of a system component. It provides a mechanism by which all participants in the industry can describe the behavior of their component across its entire life cycle. Each role in the value chain needs to help shape the definition of the metalanguage relative to its domain. A generic commercial SDR architecture provides a basis for understanding of the relevant SDR concepts, and use-cases.

9. REFERENCES

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[ITU] International Telecommunications Union, http://www.itu.int
[OMA] Open Mobile Alliance, http://www.openmobilealliance.org
[RDF] Resource Description Framework, http://www.w3.org/RDF/
[RDF Validator] W3C RDF Validation service, http://www.w3.org/RDF/Validator/
[UML] Unified Modelling Language, http://www.uml.org
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[Commercial Handset Guidelines] SDR Forum, http://sdrforum.org
[Perspectives on a Metalanguage for Configurable Wireless Systems] P.A.Subrahmanyam (Consulting Professor, Stanford University, CA.), Mark Cummings (Chairman, Board of Directors, Software Defined Radio Forum &

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