CHANGING METALANGUAGE LANDSCAPE

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ABSTRACT

Over the last several years, the authors of this paper along with a group of others in the field have proposed and worked on the standardization of a Language to support a range of functions for wireless devices, in wireless networks including:

- Efficient Life Cycle Development Provisioning, Fielding, Operation and Retirement
- Handover Between Dissimilar Network Types
- Coexistence of Dissimilar Networks in the Same Band
- Autonomous Network Configuration
- Cognitive Radio.

This language includes methods to describe capabilities (frequency bands, modulations, MAC protocols, etc.) and protocols to exchange these descriptions and to negotiate. This language can be called a Metalanguage.

Recent developments have dramatically increased the attention focused on developing this Language. These developments include:

- Femtocells
- TV White Space
- US DoD Wireless Policy Reorganization

The result of these developments is that instead of a single Metalanguage standards, a number of ad hoc standards are likely to emerge. In order to produce the best possible outcome, the technical community needs to:

- Maintain Communications Channels Between All the Ad Hoc Efforts
- Attempt to Avoid Tendencies to Overdue and Underdue
- Prepare For Downstream Harmonization

1. INTRODUCTION

The radio industry has been moving towards networks composed of “plastic” components. That is, components that can change their properties, functions, configurations, etc. This started with the emergence of multi mode multi band systems, was extended by the introduction of software download and now, continues with the gradual introduction of SDR technology.

Automated tools for design and development of hardware and software along with technology evolution in the are of software frameworks have increased productivity in the early stages of product life cycles. However, the later stages have continued to relie heavily on manual inputs. This has resulted in a situation in commercial cellular where Opex is growing faster than revenue while networks are more fragile, less robust and therefore, new service introductions are impeded. Similar situations exist in the Public Safety and Military market segments.

A number of people came to the conclusion that the solution to these problems is a standardized Language that supports automated processes through out the life cycle. This Language has variously been called a Meta Language [1-3], a Policy Language, a Functional Description Language, a Network Description Language [4], etc. What it is called is less important than what it is. This language allows radios and networks to autonomously negotiate with each other to specify and configure themselves in an optimal fashion given their capabilities, environment and the objectives of their users.

It was felt that it is important that this language is comprehensive and universal. Although it can have subsets or “dialects” it had to be a single Language. The fear was that if we ended up with multiple non-compatible overlapping languages we would find ourselves in a true Tower of Babel.

A set of forces have come together to add urgency to the development of this Metalanguage, but have also set in motion processes that could change some of the previous underlying tenets. These forces derive in part from the following developments:

- TV White Space
- Femtocells
- US DoD Wireless Policy Reorganization.

In this paper, we will discuss each of these developments, the changes they are producing, and what the technical community should do in response.

2. TV WHITE SPACE

It used to be that a MAC (Media Access Control) for wireless systems was defined by a combination of a protocol (such as CSMA/CD) and a regulatory authorization. The regulatory authorization was either by license plus equipment authorization or unlicensed band designation and equipment certification. We are now seeing the emergence of a more complex MAC. It started with dual mode cell phones in the migration from 1G to 2G (first generation analog cellular to second generation digital cellular). Cell phone MAC's had a "search function" added so that they came up in 2G and if they could not find a 2G base station, reverted to 1G. As IEEE 802.11 evolved, it came up with similar extensions. With the TV White Space Report and Order(Nov 2008), the US FCC has continued the migration to a more complex MAC.

Under the FCC White Space rules, in order for a radio to Access the White Space spectrum, it must connect with a centralized data base at required intervals, give its geographic location in longitude and latitude to see if there is any spectrum which hasn't been registered as occupied in that location by a White Space Protected User and also sense the spectrum to see if a non registered Protected User is present. Protected Users are defined by the FCC, but in general are legacy licensed users. Since one device moving into a particular section of White Space spectrum is equivalent to the sound of one hand clapping, components in a wireless communication system must communicate about objectives, changes in environment, etc. in order to coordinate with each other about accessing white space spectrum.

Over time as different wireless systems from different standards environments (such as WiFi and Cellular) try to occupy the same piece of White Space spectrum, it will be necessary for components in these different systems to coordinate (collaborate) their usage of the White Space spectrum so as to improve the quality of the communications experience for all involved.

This means that the MAC layer of devices supporting White Space usage, have to include this expanded capability at a minimum. This trend is likely to be continued with more complex sharing arrangements for both licensed and unlicensed spectrum. Some of the possibilities actively under consideration at this time include sharing spectrum between Public Safety and commercial users. The future role of the military and its associated communications systems in our increasingly complex and inter-related world is unclear, but it is also likely to involve spectrum sharing.

3. FEMTOCELLS

Femtocells are cellular base stations that are placed in a subscriber's premises and connected by subscriber provided broadband back haul. They provide the subscriber with good in door coverage and have substantial inherent operating cost advantages for the network operator in reduced expenses for:

- Premises,
- Utility Power
- Back Haul
- Field Service

However, they represent significant challenges in network configuration and operation. Senior management at leading network operators have come to the conclusion that if femtocells are handled the way current base stations are, the associated Opex increase will, not only consume all the potential savings, but also consume all current profit margins.

The only way out of this dilemma is to develop and field systems that can autonomously configure themselves. This requires a Metalanguage that the femtocells can use to negotiate with each other, so as to maximize service and minimize interference. This must be done for femtocells operating in licensed spectrum occupied only by a single cellular network operator as well as White Space Spectrum occupied by a number of network operators (both cellular and other AIS's).

4. THE DEFENSE NETWORK OF NETWORKS

Many agencies of the United States Government, including notably the Department of Defense and the Department of Homeland Security, are no longer simply network-enabled. They have become network-dependent, a state also referred to as network oriented or net-centric. Their ability to operate has become highly dependent on a heterogeneous system of communication networks. This system or cloud of networks is referred to as cyberspace.

The primary goal of the network of networks operated by the Government today is to enable users to share timely and trusted information even under changing and disruptive conditions. The current state of the various government networks makes it difficult – and in many cases impossible – for this primary goal to be achieved. Every government agency today operates multiple types of networks. Private industry invariably offers stove-pipe solutions. Even if these systems comply with a number of military and commercial standards, as a whole the resulting multiple types of networks behave in a disorganized way, as has been observed in several Defense Science Board reports. Their integration into a single interoperable network has not happened, even within a single agency, let alone on a bigger scale.

At the same time, the heterogeneity of this network of networks has increased dramatically, while the vulnerabilities of these networks have begun to threaten US national security.

In modern warfare network interoperability – or lack thereof – can make the difference between winning and losing in the battlefield. Lack of interoperability has raised serious vulnerability issues and has emerged as a key objective of the entire Department of Defense. There should be interoperability not only within DoD, but also between DoD, DHS, and in fact among all branches of the government, and coalition forces.

One approach to achieving interoperability that has been suggested is to procure all networks and components from a single supplier or from a group of suppliers who promise and deliver interoperability among their products. This method, even if feasible, is known to have a number of economic, technical, and political challenges and is not considered to be a viable long-term solution.

Another method is to rely on various military and commercial standards. This approach has been tried, but is not without problems. The standards-development process requires agreements among companies and is therefore political; it often results in platform-specific features and open-ended characteristics. Standards contain ambiguities and even contradictions. It is also worth noting that standards cover only parts of the overall networks of government agencies. This will limit interoperability to only within these parts. Independently developed standards are never compatible and in some cases in conflict with each other, reflecting the different business interests of their developers. Due to all of these problems, as important as they are, standards are insufficient to ensure end-to-end interoperability, even if they are precise and backwards-compatible with previous versions.

The current approach to achieving interoperability is to buy two different systems, which can comply with two different standards, and then customize one or both ends of the misconnection. This process results either in a proprietary system or in the development of a new standard. It is well worth noting, that according to this method the total cost to achieve interoperability increases exponentially with the number of different systems because costs are incurred every time a new system is added. For a small number of large, monolithic systems, the total cost may be acceptable. However the number of systems and networks has become too large and continues to increase. It is desirable to be able to deploy small modular systems that are interoperable with deployed systems. Therefore this current approach to achieving interoperability is no longer economically and technically feasible.

The current defense network has wired, wireless, and satellite subnetworks. In the future the DoD network, while remaining heterogeneous, must be integrated so that all subnetworks can be connected.

At all times the users should be informed of the rate and quality of network services. Before these different subnetworks can communicate, they must exchange data about their capabilities and current states. Since this data is about data, it is referred to as metadata. This metadata used to be locked up and proprietary to the different subnetworks. The metadata in many cases was not explicitly defined. For example, within one wireless system, information about carrier frequency is typically unnecessary. When this metadata is defined and shared it becomes useful beyond the original design intent for each subnetwork. In an interoperable network, the value of the metadata increases significantly. The existence and availability of metadata is essential to the use of data by different systems and services. It is important that metadata is added or tagged to the data continuously, as data is being created.

Given that metadata is necessary, should the metadata definitions be standardized? If metadata is available, but not standardized, then the different subnetworks and the applications that run on them will use incompatible metadata formats and semantics. Data structures have always been created by specific applications and it is impossible to reuse the data in other applications. For example, two different divisions of the Air Force may use two different semantics for the same aircraft – one coming from the operational mission and one coming from a maintenance perspective. Standardizing these metadata would be very helpful; otherwise there must be a system that will perform translation among the different metadata formats and semantics.

Services in the commercial world are moving from human-to-human and machine-to-human to machine-to-machine interactions. Services are no longer between consumers and providers. Users can now create innovative services themselves and share them with others. A major advantage of the Metalanguage is the reusability of services which avoids redundant development and deployment.

Multiple subnetworks can be integrated in a meaningful way only if there is some commonality. This commonality is provided from the Metalanguage. The Metalanguage has emerged as the critical enabling technology for interoperability on a wide scale. The benefits of this Metalanguage are numerous and important. It will enable radios participating in the defense wireless network operating at different frequencies and supporting different waveforms to communicate with each other. The Metalanguage will allow new software applications required by changing threads and operational doctrines to be distributed wirelessly to hardware platforms already deployed in the field.

Military networks require very high reliability. The commercial sector is motivated by profits and providing adequate service 95 % to 99 % of the time is acceptable. A military network must provide service to all users regardless of conditions. To provide satisfactory service for the last few percent is very costly – generally between 10 and up to a 100 times more - and is usually not justified in commercially industry. This may require a much more rigorous approach to metadata definitions and a Metalanguage than in the commercial industry. Therefore it is possible that there will be not one, but two or more Metalanguages. Making different Metalanguages communicate requires a gateway, a Metagateway, between the two Metalanguage domains. This Metagateway will perform not only translation among different metadata definitions, but also translation among the protocols to exchange metadata.

5. DIVERGING EFFORTS

So here we are with a growing set of requirements for a Metalanguage from a growing set of directions. How are these being responded to? It is good that there is a lot of energy going into this area from a number of groups, However, this also creates a challenge. A brief review of the active groups will help illustrate this.

3GPP is one of the most influential standards organization for the commercial cellular industry. 3GPP LTE Advanced has an active work item labeled SON (Self Organizing Networks) and there are a set of proposals addressing autonomous configuration of femtocell networks. These proposals are based on the assumption that only one cellular network operator is operating in a given area and that there is no interference issue between femtocells and base stations. It uses two parameters (vectors) and an algorithm implemented in each femtocell. The parameters are power and priority. Power is measured in two distinct fashions: the transmit power setting in a particular radio and the perceived power from a neighboring radio at that particular radio. Priority is determined by the type of information a particular femtocell needs to send. The more sensitive that information type is to latency, error, etc., that is more streaming based; the higher the priority. Each femtocell exchanges the power information and the priority of its outbound message cue to its neighbors. The algorithm is based on a mathematical process that sets each local femtocell's transmit power in such a way as to maximize quality of service for all radios in the neighborhood. This proposed solution is based on XML and a protocol engine.

IEEE 802 is another SDO that is influential. It started by developing wired, then wireless LAN standards in the 802.11 family (WiFi) and is still doing important work in WLAN's. It's scope has expanded to include WiMax, wireless personal area networks, and others. IEEE 802 has several activities underway that are significant for this discussion. The first to start was IEEE 802.21 which addresses handover between dissimilar networks. It is based on an approach that can be considered as a precursor to OWL. IEEE 802.21 was originally conceived as a mechanism to do handover between WiFi and WiMax, but became more generalized. The IEEE 802.21 proposal and a simpler approach that is more data base like were brought to 3GPP. 3GPP adopted the OMA approach.

IEEE has organized several other groups working on White Space related activities. These groups include IEEE 802.19 TV White Space Coexistence Study Group, IEEE 802.22, and IEEE 802.11 TV White Space Study Group. It is expected that the Study Groups will soon become Working Groups producing standards.

These groups illustrate a trend in the commercial wireless standards arena. No group wants to allow an outside force to determine how they will implement changes to accommodate White Spaces. What results is that each group has an internal effort plus a closely allied umbrella effort working on coexistence.

IEEE P1900.4 is composed primarily of Asian and European commercial cellular network operators. It is attempting to provide more of a generalized umbrella. They have published a generalized architecture shown in Figure #1. In their model, the line between the two boxes labeled RAN Selection carries the Metalanguage. The group is beginning to work on specifying these interfaces.

IEEE P1900.5 is composed primarily of USA DOD personnel and DOD supported groups and individuals. It is working in cooperation with the SDR Forum MLM Working Group which has a similar composition. Although still in an early stage, these two groups are working on a Metalanguage based on OWL and inference engines.

It should be noted that the MLM working Group appears to have been the first group to actively work on the Metalanguage problem and as such, has played an important role in getting attention focused on the problem.

What is emerging, then, is a situation where the military is developing a Metalanguage solution based on OWL and inference engines, while the commercial industry is developing solutions based on XML and protocol engines.

It is important to note two things about the commercial solutions. The first is the presence of the "s". There are a number of ad hoc solutions appearing. This is driven by the previously mentioned fact that many groups "want to control their own destiny", and also want quick easy solutions to immediate near term problems. This brings us tot he second thing: that many in the commercial segment want simple solutions. In fact, some may argue that XML is too complicated.

There are similar but contrasting things to note about the groups working on a military solution. First, there is no "s". This is a good thing. However, the same forces are at work in the groups dominated by military supported groups and individuals that were at work in the early days of the standards efforts that led to JTRSS.

Without active intervention, there is the very real possibility of multiple divergent Metalanguage solutions. We could have a military solution that purports to be early to market and is overly complex, too expensive, and so divorced from the commercial world that it can not take advantage of commercial economies of scale. While the commercial groups create an overly simple set of overlapping, somewhat non compatible, solutions which appear to meet near term requirements, but don't fully address the true problem while not being able to take advantage of the earlier military investment.

6. OPTIMIZING THE OUTCOME

Intervention can not solve all the problems, but it can make the situation substantially better. It is unlikely that any intervention can prevent the appearance of multiple ad hoc solutions. The, "control our own destiny" desire is too strong. Also, there are those that argue, that multiple solutions are more likely to lead to the best result (allowing the solution to have more degrees of freedom than the problem).

In any, case we should be prepared for multiple groups working on the problem from multiple perspectives. Given this what can be done to optimize the output? The first, and most important thing is to foster communication between these groups. This sounds simple, but it requires people to get out of their comfort areas. That is, it is necessary for people active in military standards groups to attend commercial standards groups and to invite contributors to those commercial standards groups to attend the military groups. Second, so far as possible, the barriers that prevent participation by the other side (military in commercial; commercial in military) within the standards groups should be lowered. Third, there needs to be financial support for this cross segment activity. One of the key objectives, here, should be to help the industry as a whole to avoid both over shooting and undershooting.

Next, support appropriate activities at appropriate levels. That is, allow each SDO to have local control as far as possible. The best way to do this is to allow these SDO's to focus on changes to the Phy and lower levels of the MAC necessary for ad hoc solutions in their domain. Then support umbrella efforts at the upper layers of the MAC and MAC extensions to promote harmonization and to support coexistence, interoperability, autonomous organizations, etc. These umbrella efforts may be tiered. For example there could be an umbrella within IEEE 802 for all 802 standards and another umbrella within 3GPP for all cellular standards. Then a second tier umbrella could provide links between these two.

These umbrellas should be so constructed that they allow adoption by existing semiconductors, components, and radios with the minimum of physical changes. While at the same time, allowing for easy evolution over time to more robust solutions.

6. CONCLUSION

In this paper we have briefly reviewed the requirements for a Metalanguage that will reduce the cost while improving the quality of service that wireless networks can provide and how those requirements in different market segments and SDO's are leading to multiple non compatible overlapping ad hoc solutions which may not meet the true needs. We have then recommended a set of steps that can be taken which will improve the outcome. These steps include:
Communication
Cross Market Segment Cooperation
Financial Support for Cross Market Segment Participation
Tiered Standards Efforts With Phy / Low Level MAC in The Home SDO and High Level MAC / MAC Extensions in Umbrella Standards That can Support Harmonization

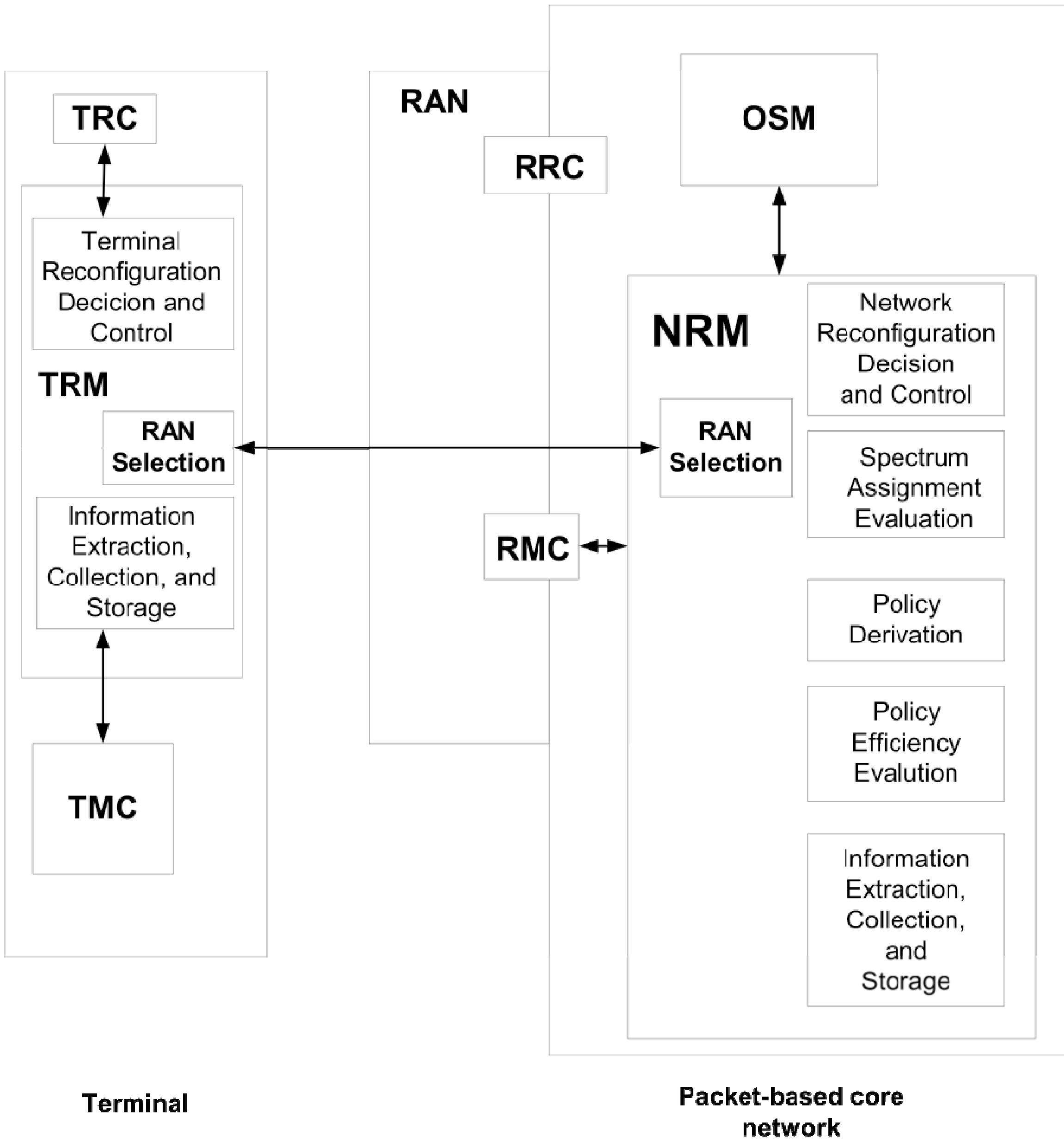

Figure 1. IEEE P1900.4 architecture

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