PERSPECTIVES ON A METALANGUAGE FOR CONFIGURABLE WIRELESS SYSTEMS

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ABSTRACT

Driven by the desire to support "anytime, anywhere, customizable, on demand" services, wireless systems are increasingly becoming more heterogeneous and configurable. In order to alleviate the complexity of designing, deploying and managing such networks, it is useful to have a means for uniformly describing the components in these networks, at varying levels of detail. Such descriptions support tasks that involve communications with, and interaction among different hardware and software components within and between devices in networks. It is both useful and important to have a metalanguage for this purpose. Such a metalanguage must be able to interface with existing standards that are domain specific; it must also serve the needs of the various participants in the value chain, including network operators/enterprises, system manufacturers, component vendors, regulators, and end users..

1. INTRODUCTION & BACKGROUND

In order to support universal availability, the wireless industry is evolving to networks composed of nodes whose basic RF capabilities are flexible and configurable. Aspects of such capabilities are already visible in the current generation of multi-mode/multi-band infrastructure and terminal systems e.g., basestations, acess points, mobile handsets, etc. and the functionality offered by over-the-air software download. The growing sophistication of configurable systems technologies and software-defined radios is further catalyzing this evolution.

Concomitantly, it is becoming generally accepted that the historic (and current) method of authorizing spectrum use–hardwired authorization of spectrum–results in an apparent scarcity of spectrum that can be avoided by the proper application of dynamic spectrum sharing techniques. As a consequence
, Regulatory agencies are trying to make spectrum usage efficient enough to allow the majority of the population of the world to be connected the majority of the time at higher and higher bandwidths.

At the same time, the equipment segment of the industry is transitioning from an industrial model to a consumer electronics model, ie, from a small number of large vertically integrated system vendors to a rapidly growing number of technology, semiconductor and software providers.

A typical carrier network today involves multiple device types, multiple networks (perhaps across different geographies), and multiple air interface standards (AIS's such as CDMA2000, UMTS and IEEE 802.11a/b/g). Examples of (sub)systems include infrastructure components, such as access points and base stations, as well as terminal devices such as Mobile Handsets and Personals Digital Assistants (PDAs), etc. These systems in turn consist of multiple software, and hardware components.

The complexity spawned by this multiplicity of devices, networks and air interface standards, is further compounded by the existence of multiple versions of software and plug in hardware that are deployed to systems in the field. This complexity gives rise to the considerable challenges in provisioning, deploying, and managing such systems

2. RATIONALE FOR A METALANGUAGE

In an end-to-end reconfigurable system, there are various tasks that require interactions with different components in the network, and that require such components to communicate with each other. Example tasks relate to network configuration, device reconfiguration (involving download of applications/firmware), and network operation (provisioning new services, upgrades, roll out of new AIS's, etc.). Depending on the nature of the specific task, network elements need to be queried, controlled, modified and managed, at varying levels of detail.

It is both useful and important to have a (meta)language that supports these tasks. Such a metalanguage must be able to interface with existing standards that are domain specific; it must also serve the needs of the various participants in the value chain, including regulators, system manufacturers, component vendors, and network operators/enterprises.

Entities involved in the value chain

Some of the key players involved in the wireless value chain include

- Mobile Operators, including Mobile Virtual Network Operators (MVNOs);
- Enterprises that operate corporate networks;
- System vendors;
- Semi-conductor and component vendors;
- Software vendors;
- Regulatory agencies;
- End users

A metalanguage needs to gracefully interface with the legacy domain specific languages and methodologies that are already prevalent in each of these domains. Use case scenarios that represent the perspective of the participants listed above must drive the key characteristics required of the metalanguage.

Carriers

A typical wireless carrier/network operator today is faced with an explosion in the number of device profiles and configurations that are deployed within the network. For example, it is not unusual for a carrier to have a subscriber base on the order of a 100 million subscribers and employ on the order of 5 handset vendors who provide from10 to 50 product lines each, that turn over every six months. In addition, there are a growing number of infrastructure vendors, recently catalyzed by the existence of organizations such as CPRI and OBSAI. With the increasing reliance on field upgrades, a single network can have from 10 to 100 thousand configurations in the field. The result of this growing complexity is analogous to the Mars rover problem. Instead of one device 100 million Kilometers away with a software configuration problem, the operator has to deal with 100 Million devices within a mile of a basestation, each with a different configuration!

It remains very difficult to roll out new revenue generating service offerings, many of which rely on leveraging the attributes/functionality of the mobile devices/handsets deployed in the field. Examples of such offerings that leverage configurable RF devices include Voice over IP services over Wireless Local area networks (VoIP over WLAN), seamless roaming between regions that have different AIS footprints, upgrades of new handset functionality, and the introduction of new applications and services, including gaming and user/location dependent applications.

System Vendors

System vendors are challenged to produce differentiated products while coping with the usual time and cost pressures. If a vendor chooses to use a reference design, the development cycle involved is relatively low risk, but the differentiation is also minimal.

In order to produce a differentiated product, system vendors need to source their own parts, and leverage new, improved and/or disruptive technology. The large number of sources can be daunting leading to fears of higher risks and longer times to market. This can be exacerbated by limitations in availability of sophisticated RF engineering talent.

Chip & Component Suppliers

Chip and component suppliers are faced with shrinking product life cycles, increasing product complexity, and lengthening sales cycles. In order for their business to succeed, they need to get their product designed in to the target system as quickly and inexpensively as possible. With the increasing specialization that is taking place in the industry, smaller suppliers often ask: Do I need a reference design? Do I necessarily have to produce a complete reference design? Can I produce and sell individual components, or do I have to make the entire chip set?

A meta language by making it easier for Systems Vendors to source components creates an enviroment where Chip and component suppliers can reduce their sales cycles and ease the integration of their parts in complete systems.

Software vendors

Software vendors need to develop application software and firmware for both infrastructure and terminal devices. A common mechanism is needed for determining the capabilities of various devices in the network, and and the functionality of the H/W and S/W components they contain in order to determine what S/W will work. This needs to be done at design time, provisioning and field upgrade. The metalanguage provides a means to do this.

Regulatory Agencies

Regulatory agencies include, for example, international regulatory agencies such as the International Telecommunication Union (ITU); regional regulatory agencies, such as the European Telecommunications Standards Institute (ETSI); and national regulatory agencies such as the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) in the US and their counterparts worldwide.

As mentioned earlier, regulatory authorities are attempting to gradually explore incremental changes in the historic (and current) method of "hardwired" spectrum authorization, realizing that this causes an apparent scarcity of spectrum that can be avoided by the proper application of dynamic spectrum sharing techniques.

Next generation adaptive/flexible radios will be able to utilize available spectrum intelligently based on knowledge of actual conditions rather than using current conservative spectrum management methods that consists of static spectrum assignments. This will enable much more efficient utilization of spectrum than is possible today.

At the same time, regulators are concerned with assuring that devices only operate in an authorized fashion. The complexity of this problem is compounded by the availability of software download capabilities that can potentially alter RF characteristics of a device, and the existence of thousands of permutations and combinations in the installed base. A metalanguage with formal syntax and semantics can assist in this task. While agile radio capabilities improve spectrum utilization and spectral efficiency, regulators also have concomitantly to cope with faster product certification and shrinking budgets. A metalanguage can help here as well.

End Users

The end user, while not a primary participant in the development of the technology, is ultimately the eventual consumer, and hence forms a critical link in the value chain. The primary requirements for an end user is to have cost-effective, reliable, and ubiquitous access to relevant services that complement his/her lifestyles. The nature of desirable services will vary widely depending on the requirements of specific individuals, from being basic reliable voice services, to high speed data and media services. At the very least, a nominal service should be transparent to location, and be portable within a home, from home to the transportation system, and from the transportation system into next home, office, shopping mall, factory, hospital, etc..

Terminal devices that support configurable radio capabilities play a key part in being able to deliver cost-effective, new services to the user. These services can be delivered in a location sensitive fashion by appropriate network policies. In order to deploy these services, it is important to discern the capabilities of specific user/mobile terminals/handsets.

Elements in a Configurable Wireless Network

Many network elements, specially hardware (sub) systems, software (sub)systems, embedded (sub)systems and network components, already have domain specific techniques for their description. Indeed, in many cases, there exist multiple such mechanisms. While it necessary to be able to communicate with these systems/components, it is imperative to be able to do this in a way that does not disrupt existing paradigms, and in a manner that does not try to reinvent the wheel.

For example, there are several language standards such as Verilog, VHDL, SystemC, and SystemVerilog that are commonly used in the context of hardware descriptions. Additionally, a plethora of languages has been used in the software development context, such as C/C++/C# and Java, as well as modeling frameworks built around UML and variants thereof [UML]. Further, specialized languages have evolved or become de-facto standards in some domains, e.g., MATLAB for Digital Signal Processing (DSP) applications. While these may not necessarily have all of the desired attributes, it is important to interface with existing standards for the different components in a network in a harmonious fashion.

A metalanguage that enables tasks across an end-to-end reconfigurable system needs to provide a means to capture relevant aspects of the behavior/attributes of a system/component. It further needs to have formal syntax and semantics so as to enable machine representation and manipulation.

Because of the widespread use of XML based mechanisms, it is attractive for a metalanguage basis to be compatible, if appropriate, with XML based representations. A complementary approach is to interface via such a metalanguage to Application Programming Interfaces (APIs) that have been developed for specific domains of interest.

3. REPRESENTATIVE DIMENSIONS

We now provide some additional examples of representative efforts that are relevant to the overall thrust of this discussion.

Spectrum Policy Languages

Next generation adaptive/flexible radios will be able to utilize available spectrum intelligently based on knowledge of actual conditions rather than using current conservative spectrum management methods that consists of static spectrum assignments. This will enable much more efficient utilization of spectrum than is possible today.

Furthermore, without the need to statically allocate spectrum for each use, new networks can be deployed much more rapidly. This is particularly true in both military and emergency response scenarios. Ad hoc networks as well as agile radio networks can be formed.

The term *spectrum policy* refers to any externally (to the radio) imposed rules for spectrum use. A radio that is capable of dynamically utilizing spectrum must be able to adhere to rules corresponding to the many uses of which it is capable–not just one use, as with most current radios.

Next generation radios will be expected to operate over a wide range of frequencies and within different geopolitical regions. Therefore, they must incorporate a real-time adaptive mechanism for conforming to the policies applicable to each situation.

Spectrum policy specification languages based on XML, and variants of DAML (DARPA Markup Language) are being developed in this context, and it is useful to accommodate these perspectives when developing a network-wide metalanguage.

Enhanced Device Profiles and Descriptions

Different types of web-enabled devices have different input, output, hardware, software, and network capabilities. In order for a web server to provide optimised content to different clients it requires a description of the capabilities of the client, referred to as the delivery context. Two standards have been created for describing delivery context: Composite Capabilities / Preferences Profile (CC/PP) created by the Worldwide Web Consortium (W3C) and User Agent Profile (UAProf) created by the WAP Forum. These standards have been since been amalgamated into ongoing standardization activities in the Open Mobile Alliance [OMA].

The description capabilities inherent in CC/PP and UAProf, while potentially adequate for the purpose of display and browsing, are somewhat inadequate for other tasks, such as software downloads for applications and firmware downloads for RF configurability. It is therefore reasonable to presume that standards that support these and other important tasks will evolve under the aegis of relevant bodies, such as the Open Mobile Alliance (OMA) and the Software Defined Radio (SDR) Forum. To a larger extent, the emphasis of these efforts is complementary, since the SDR forum is focused on the RF functionality and capabilities, while the OMA has historically focused on the higher levels of the interface.

Reconfiguration Procedures

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 dicussed 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.

4. 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.

5. SUMMARY AND CONCLUSIONS

Wireless systems are increasing 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. 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 and biometric subsystems. Further, the design of such infrastructure 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 various players.

6. REFERENCES

[ETSI] http://www.etsi.org European Telecommunications Standards Institute
[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