Achieving Interoperability with IEEE 802.16-Compliant Systems

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ABSTRACT

The IEEE 802.16 Air Interface Standard is truly a state-of-the-art specification for fixed broadband wireless access systems employing a point-to-multipoint (PMP) architecture. It was developed with the goal of meeting the requirements of a vast array of deployment scenarios, in particular those networks operating between 11 and 66 GHz frequencies. As a result, only a subset of the functionality is needed for typical deployments directed at specific markets. Additionally, the IEEE process stops short of providing conformance statements and test specifications. In order to ensure interoperability between vendors competing in the same market, a non-profit group was formed, the Worldwide Interoperability for Microwave Access (WiMAX) Forum, which was created by the leaders in above 11 GHz IEEE 802.16 technology. WiMAX addresses these issues by developing system profiles and by producing ICS proforma, Test Suite Structure and Test Purposes specifications and Abstract Test Suite specifications according to the ISO/IEC 9464 series of conformance testing standards.

OVERVIEW OF IEEE 802.16

Task Group 1 of IEEE 802.16 was started approximately two and half years ago with the charter to develop a point–to-multipoint broadband wireless access standard for systems in the frequency range 11-66 GHz. The standard was to cover both the Media Access Control (MAC) and the physical (PHY) layers. The IEEE 802 process favors the submission of complete system proposals as a starting point for the creation of the standard. Initially, there were numerous proposals, but eventually it was narrowed down to two: a proposal based on wireless DOCSIS (also known as DOCSIS+) and a proposal based on Ensemble Communication's proprietary technology, known as Adaptix (with notable input from Nokia and other companies). It became clear that neither the DOCSIS proposal based on cable technology, nor the Ensemble proposal based on a next-generation, state-of-the-art set of technologies would achieve the necessary 75 percent vote to become the sole basis for the standard.

The proposals were already compatible in many basic aspects, and in May of 2000, the process of merging the two competing proposals began. The basic layering, bandwidth (BW) request scheme, ability to transport any application layer, and support of advanced physical layers were taken from the Ensemble proposal. The flexible message structure, authentication, and security were taken from the DOCSIS proposal. Over the course of the next year, the combined system specification was improved based on comments from a large number of sources.

A number of PHY considerations were taken into account for the target environment. At the frequencies considered, line of sight is a must. This requirement eases the effect of multipath, allowing for wide channels, typically greater than 10 MHz in bandwidth. This gives IEEE 802.16 the ability to provide very high capacity links on both the uplink and the downlink. Adaptive burst profiles (modulation and forward error correction (FEC)) are used to further increase the typical capacity of 802.16 systems with respect to older technology. The PHY is also designed to accommodate either Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD) deployments, allowing for both full and half-duplex terminals in the FDD case.

Similarly, the MAC was designed specifically for the PMP wireless access environment. It is designed to seamlessly carry any higher layer or transport protocol such as ATM, Ethernet or Internet Protocol (IP), and is designed to easily accommodate future protocols that have not yet been developed. The MAC is designed for the very high bit rates (up to 268 mbps each way) of the truly broadband physical layer, while delivering ATM compatible Quality of Service (QoS) to ATM as well as non-ATM (MPLS, VoIP, etc.) service.

The basic frame structure is shown in the following Figure.

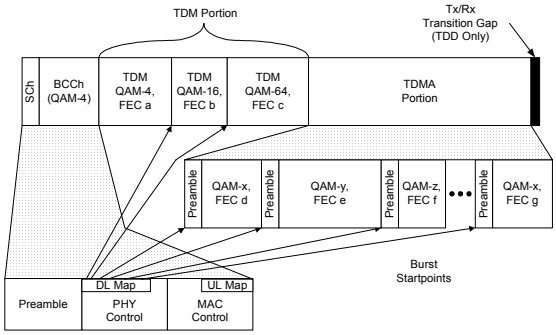

Figure 1: Basic Frame Structure

The frame structure allows terminals to be dynamically assigned uplink and downlink burst profiles according to their link conditions. This allows a trade-off between capacity and robustness in real-time, and provides roughly a two times increase in capacity when compared to non-adaptive systems, while maintaining appropriate link availability.

The 802.16 MAC uses a variable length Protocol Data Unit (PDU) along with a number of other concepts that greatly increase the efficiency of the standard. Multiple MAC PDUs may be concatenated into a single burst to save PHY overhead. Additionally, multiple Service Data Units (SDU) for the same service may be concatenated into a single MAC PDU, saving on MAC header overhead. Fragmentation allows very large SDUs to be sent piece-meal to guarantee the QoS of competing services. And, payload header suppression can be used to reduce the overhead caused by the redundant portions of SDU headers.

The MAC uses a self-correcting bandwidth request/grant scheme that eliminates the overhead and delay of acknowledgements, while simultaneously allowing better QoS handling than traditional acknowledged schemes. Terminals have a variety of options available to them for requesting bandwidth depending upon the QoS and traffic parameters of their services. They can be polled individually or in groups. They can steal bandwidth already allocated to make requests for more. They can signal the need to be polled, and they can piggyback requests for bandwidth.

As can be seen, by the time authentication, security, capability negotiation and a host of other features are added, the IEEE 802.16 standard becomes almost overwhelming.

THE INTEROPERABILITY CHALLENGE

Plethora of Options

From the preceding overview, it is clear that the IEEE 802.16 Air Interface Specification is a very large specification. It was designed to cover the fixed broadband wireless access needs of a variety of different situations. There are allowances for different physical layers for different frequency bands and country-by-country frequency use restrictions. There are features that allow one to build an IP centric system or an ATM centric system depending upon the needs of customers. The specification is designed to cover application to diverse markets from very high bandwidth businesses to SOHO and residential users.

Because of the wealth of options available, an implementer currently faces a tough decision. Do you build an IEEE 802.16 compliant system implementing every possible feature, even those features you know will never be used in systems for your target customers? Or, do you build a system with only the subset of features you need for your market, risking accusations of non-compliance and lack of interoperability?

The IEEE 802.16 working group has started to address this issue by the inclusion of Chapter 12, “System Profiles” in the IEEE 802.16 specification. The purpose of these system profiles is to specify which features are mandatory or optional for the various MAC or PHY scenarios that are most likely to arise in the deployment of real systems. This allows vendors addressing the same market to build systems for that market that are interoperable while not requiring the implementation of absolutely every feature.

Unfortunately, this portion of the standard is in its infancy. Additionally, as new markets and new system scenarios emerge, the industry cannot operate on the schedule required to form a task group under IEEE 802.16 to create new profiles and take it through all the procedural steps required to officially publish an amendment to the standard. New profiles must be created by industry agreement in a more timely fashion, and then rolled back into amendments to the standard at the slower pace endemic to the formal process.

No Test Specifications

Another issue facing IEEE 802.16 developers is an artifact of the IEEE standards process concentrating primarily on requirements. The output of the IEEE 802.16 working group is a standard, that is to say, a requirement specification. The working group will continue to expand the standard to cover additional markets. This continuing work will result in amendments to the standard, but they will still address requirements. There is no work item in IEEE 802.16 to address the creation of test specifications.

Test specifications are necessary to:

- Ensure that equipment and systems claiming compliance to the standard or a profile have been sufficiently tested to demonstrate that compliance.
- Guarantee that equipment from multiple vendors has been tested the same way, to the same interpretation of the standard, increasing the interoperability of the equipment.
- Enable independent conformance testing, giving further credibility to the previous two items.

This test specification initiative is an area where the ETSI has an official process and is typically more complete than the IEEE process. ETSI

follows the guidelines of the ISO/IEC 9646 series (ITU-T X.29x series). The Test Suite Structure and Test Purposes (TSS & TP) document and the Abstract Test Suite (ATS) specification, both described in ISO/IEC 9646-2 (ITU-T X.291), suit the purpose particularly well.

No Conformance Statements

A final issue facing developers of IEEE 802.16-compliant systems is that having profiles is only part of the interoperability challenge. There must be a standard method of identifying which profiles a device or system complies with and which optional features are implemented so that system integrators can make educated decisions about specific features to provide to customers and to aid in the selection of equipment.

Conformance statement development is not an official part of the IEEE standards process. The IEEE process concentrates on the specification of requirements. This leads to the tendency to build systems that do much more than they need to and the likelihood of accusations that standards to not specify interoperable systems. In contrast, the ETSI process generally addresses this issue by the development of Implementation Conformance Statement (ICS) proforma documents, following the guidance of ISO/IEC 9649-7 (ITU-T X.296). The most common form of ICS is the Protocol ICS or PICS proforma.

For IEEE 802.16 equipment, an ICS proforma is a perfect means of describing the MAC protocol and PHY features that are required for various system profiles. An ICS proforma is also a necessary tool for vendors to specify their level of compliance and to specify which optional features have been implemented.

THE SOLUTION

The WiMAX Forum

Because of the pieces missing in the IEEE process, the non-profit Worldwide Interoperability for Microwave Access (WiMAX) Forum was created by the leaders in above 11 GHz IEEE 802.16 technology. This forum's goal is to promote broadband wireless access above 11 GHz by using a global standard and certifying interoperability of products and technologies and is open to anyone involved with these systems. The IEEE 802.16 standard provides a future-proof platform, but to achieve system interoperability, system profile definitions must be developed. Additionally, an interoperability test plan (in this case, in the form of TSS & TP and ATS specification) is necessary to ensure proper implementation of the interoperable set of features.

The profiles and test specifications are created by the WiMAX Forum, but actual testing is done by an authorized, independent laboratory. For each system profile, functions are separated between mandatory and optional feature classes by the ICS proforma document. There can be differences from one equipment manufacturer to another in implementing optional features, but mandatory features will be same in every vendor's product. Implementation of an optional feature is noted when the vendor fills out the ICS proforma.

System Profiles for 10-66 GHz

WiMAX currently is defining two MAC system profiles:

- Basic ATM system MAC profile
- Basic IP system MAC profile

Two primary PHY system profiles are also being defined:

- 25 MHz wide channel for (typically for U.S. deployments) use in the 10-66 GHz range.
- 28 MHz wide channel for (typically European deployments) use in the 10-66 GHz range.

The PHY profiles are the same except for their channel width and their symbol rate, which is proportional to their channel width. Each primary PHY profile has two sub-profiles – FDD and TDD.

MAC System Profiles

At the time of this document, the Basic IP System Profile was still under investigation. The Basic ATM System Profile had the following highlights:

- PVCs are mandatory.
- SVCs and soft-PVCs are optional.
- Support of VC switched connections is mandatory.
- Support of VP switched connections is mandatory.
- ATM payload header suppression is mandatory as a capability, but may be turned on or off on a per connection basis.
- Only enough of the packet convergence sublayer need be implemented to support secondary management connections.
- Packing of multiple ATM cells into a single MAC PDU is mandatory as a capability, but may be turned on or off on a per connection basis.
- Fragmentation of SDUs on ATM traffic connections if not a required capability. (Note that simultaneous fragmentation and packing of ATM cells on a connection would require that the ATM connection be treated as a variable-length packet connection.)
- Fragmentation and packing on 802.16 MAC management connections must be supported.

- ARQ is optional.
- MAC sublayer CRC is optional (redundant or unnecessary for ATM connections).

PHY System Profiles

The PHY system profiles have the following highlights:

- Symbol rate - 22.4 Mbaud (28 MHz channel) or 20 Mbaud (25 MHz channel).
- Roll-off factor - 0.25 required.
- Uplink modulations – SS: QPSK; BS – QPSK and 16QAM required. Others optional.
- Downlink modulations – SS and BS: QPSK and 16QAM required. 64QAM optional.
- FEC – Reed-Solomon or Reed-Solomon with Inner (24,16) block convolutional code are required. Other FEC choices are optional.
- Capability to shorten the last codeword of a burst is required.
- Frame length of 1 millisecond is required.

Documents: PICS, TSS&TP, ATS

WiMAX will produce the following technical documents:

- ICS proforma, per ISO/IEC 9646-7, describing mandatory and optional features for each system profile, enabling developers to state support for features.
- TSS & TP document, per ISO/IEC 9646-2, for the system profiles.
- ATS specification, per ISO/IEC 9646-2, for the system profiles.

In addition, WiMAX will develop subsections for inclusion is section 12 of the IEEE 802.16 Air Interface Specification for each of the system profiles.

Certification Procedure

The goal of WiMAX is to have 802.16 compliant systems certified as being compliant to selected system profiles. The verification of compliance will, ideally, be carried out by certified, independent test facilities. Based on the outcome of independent testing, WiMAX will grant certification for the equipment and approve the right to display a WiMAX certification mark on that equipment.

Initially, however, there may be systems and equipment claiming to be compliant with WiMAX system profiles before there are certified independent test facilities. To accommodate this, initial systems will be allowed to be self-verified. Vendors would be required to submit formal test documentation showing that the equipment in question passed the tests that would have been performed by an independent test facility, had one existed.

FUTURE PATHS

Update IEEE 802.16 Specification

WiMAX's objective is that system profiles will be part of Chapter 12 of the IEEE 802.16 specification. The forum is not targeting to do standardization work itself, but influence the BWA industry to cooperate for mutual benefit and more efficient standardization work in the future. Competing standards are detrimental to the industry. Incorporation of the system profiles into the actual 802.16 standard is of utmost importance.

Expand Below 11 GHz

At the time of creation of this paper, the task groups within 802.16 responsible for amendments to support systems operating below 11 GHz were still six months to a year away from finalizing the requirements in these frequency ranges. These systems will generally address a different market than addressed by the above 11 GHz systems. Nevertheless, the specification efforts in these lower bands will face the same need for interoperability. This need will be coupled with the vastness of the IEEE 802.16 specification and the fact that the IEEE process does not ensure interoperability, and thus relies on objective third-party groups support the final steps of standardization. When the sub 11 IEEE 802.16 tasks groups are ready, they need to follow the same or similar process to that taken by WiMAX. In the future, it is possible that WiMAX will either expand to cover these additional system scenarios or provide support to these groups.

REFERENCES

[1] IEEE P802.16/D4-2001 (7/24/2001): "Local and Metropolitan Area Networks – Part 16: Standard Air Interface for Fixed Wireless Access Systems".

[2] ISO/IEC 9646-1: "Information technology – Open Systems Interconnection – Conformance testing methodology and framework – Part 1: General concepts."

[3] ISO/IEC 9646-2: "Information technology – Open Systems Interconnection – Conformance testing methodology and framework – Part 2: Abstract test Suite Specification."

[4] ISO/IEC 9646-7: "Information technology – Open Systems Interconnection – Conformance testing methodology and framework – Part 7: Implementation Conformance Statements."