Global Standardization Efforts of BWA Systems Based on Cable Modem

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Abstract

Data-over-Cable Service Interface Specifications (DOCSIS) developed by Cable Labs has been adopted by International Telecommunication Union (ITU) as draft Recommendations in ITU-T and ITU-R [1,2], which are expected to be officially approved in May 2000. Nortel Networks has been spearheading the BWA standards efforts in ITU-R, ITU-T and recently in IEEE 802.16, that uses the cable modem specifications as basis for **wireless** access systems in order to achieve economies of scale. The cable modem technical parameters for physical and media access control layers have been **adapted** to the wireless environment to support bidirectional wireless access system for interactive services.

This paper presents the BWA physical and Media Access Control (MAC) standardization efforts that are in progress in IEEE 802.16 in the 10-40 GHz band, with focus on LMDS (Local Multipoint Distribution Service) band in U.S. Nortel Networks is leading the effort to standardize the DOCSIS based parameters for PHY/MAC standardization in IEEE 802.16. The services that will be supported by BWA systems include fast internet access (supporting both IP and ATM traffic), video and interactive television. The key features of this BWA system are multiple Quality of Service (QoS) support, dynamic service management, support of real-time services along with cryptographic authentication of the users for protection against theft of service.

Introduction

Broadband Wireless Access (BWA) systems are expected to be deployed as an alternative to wired 'last-mile' broadband access technologies such as cable, fiber or xDSL, due to its ease of deployment and low infrastructure costs. These systems will use point-to-multipoint architecture able to support broadband transmissions of 2 Mb/s or more (with bandwidth-on-demand access) for small/medium businesses. BWA systems will be deployed in the LMDS band in the U.S.A. defined as:

Block A: 1150 MHz (27.5-28.35 GHz, 29.1-29.25 GHz and 31.075-31.225 GHz)
Block B: 150 MHz (31-31.075 GHz and 31.225-31.3 GHz)

Similar allocations are also allocated in Canada termed as 'LMCS' (Local Multipoint Communication Service).

The DOCSIS design for cable modems was chosen and adapted to BWA because of its proven robustness and availability of chip sets. By reusing the DOCSIS design as much as possible it was envisioned that product design for BWA will have:

- reduced cost by reuse of DOCSIS chips with minimal modifications
- shorten the time-to-market allowing for rapid deployment

The major changes to DOCSIS design for use by BWA systems is in the PMD (Physical Media Dependent) sublayer where the parameters such as channel bandwidth (typically 40 MHz against 6MHz in cable), programmable Reed-Solomon block coding and preambles for reduced SNR for a given BER , support of higher symbol rates and modulation formats.

At present the standards activity in IEEE 802.16 is focused on standardizing the BWA systems for volume deployment and is planning to release the Physical and MAC standards by January 2001. This standards body is liaising with the ETSI BRAN project for alignment with European standards activity. Nortel

Networks is actively participating in IEEE 802.16 to facilitate standards of BWA based on cable modem specifications adapted for wireless environment in ITU-R and ITU-T [1,2] for achieving economies of scale.

The second section discusses the modifications made to cable modem parameters for PHY/MAC work in detail and the third section details the progress in IEEE 802.16. The final section provides the summary.

ITU draft standards for BWA

ITU has developed BWA Recommendations based on DOCSIS standards as specified in ITU-T draft Recommendation ITU-T J.116 (Annex B) [1] and ITU-R draft Recommendation ITU-R F.BWA [2] in 1999 and expected to be approved as Recommendations in May 2000.Nortel Networks has been very active in the committees that have developed these two draft Recommendations, in particular, ITU-T Study Group 9 (J.116) and the ITU-R Joint Rapporteur Group 8A-9B (F.BWA). These draft Recommendations use ITU-T Recommendations J.112 [3] and J.83 [4] for cable modems as the **basis** for **wireless** access systems. The technical parameters have been adapted to the wireless environment rather than for a cable environment in order to support bidirectional data over broadband **wireless** access systems for interactive services. The specifications in these ITU standards are based on DOCSIS 1.0. [5]

Physical Layer (PHY)

The broadband wireless access (BWA) system uses time division multiple access (TDMA). The key functional characteristics are the following:

- two-way wireless transmission based on FDD (Frequency Division Duplexing)
- downstream uses TDM (time division multiplex);
- upstream uses TDMA (time division multiple access);
- One or more upstream carriers may be supported for a single downstream carrier;
- frequency bands between *10 to 40 GHz* will be used;
- a BTS service area is called a cell, with a cell radius typically <15 km, depending on rain regions and the availability requirement;
- a cell may be divided into multiple sectors and each sector may have multiple downstream RF carriers;
- the system must be able to combat rain fades up to 30 dB and a fade rate of 5 dB / sec.
- configurable downstream channel equalization and upstream burst pre-equalization

The **upstream** Physical Media Dependent (PMD) sublayer uses a FDMA/TDMA burst modulation format, which provides variable symbol rates and two modulation formats (QPSK, 16 QAM and optionally 64 QAM). The modulation format includes pulse shaping for spectral efficiency, is carrier-frequency agile, and has selectable output power level. The PMD sublayer format includes a variable-length modulated burst with precise timing beginning at boundaries spaced at integer multiples of 6.25 microsec apart. The burst size is defined by number of minislots. The minislot consists of one or more integer multiples of 6.25 microsec timing tick. Each burst supports a flexible modulation, symbol rate, preamble, randomization of the payload, and programmable FEC encoding. All of the upstream transmission parameters associated with burst transmission outputs from the BWA CPE Modem are configurable by the BWA BTS Modem via MAC messaging. Many of the parameters are programmable on a burst-by-burst basis. The symbol rates are variable and can support upto 20.48 Msymbols/sec.The upstream PMD sublayer should support *a minimum* of 25% Nyquist square root raised cosine shaping.

The **downstream** PMD sublayer supports QPSK, 16 QAM and optionally 64 QAM modulations with variable symbol rates upto 34.78 Msymbols/sec. and supports a variable-depth interleaver with the exception for those services with latencies greater than 4 msec. The interleaver depth, which is coded in a

4-bit control word contained in the FEC frame synchronization trailer, always reflects the interleaving in the immediately-following frame. In order to improve **demodulation,** MPEG framing facilitates common receiving hardware for both video and data, and provides an opportunity for possible future multiplexing of video and data over the PMD sublayer bitstream. A sublayer is interposed between the downstream PMD sublayer and the Data-Over-BWA MAC sublayer. The downstream bitstream is defined as a continuous series of 188-byte MPEG [4] packets. These packets consist of a 4-byte header followed by 184 bytes of payload. The header identifies the payload as belonging to the Data-Over-BWA MAC. Other values of the header may indicate other payloads. The mixture of MAC payloads and those of other services is optional and is controlled by the BWA BTS Modem.

Media Access Control (MAC) Specification

The MAC sublayer defines a single transmitter for each downstream channel - the BWA BTS Modem. All BWA CPE (Customer Premises Equipment) Modems listen to all frames transmitted on the downstream channel upon which they are registered and accept those where the destinations match the BWA CPE Modem itself or CPEs reached via the BWA modem to CPE Interface port. BWA CPE Modems can communicate with other BWA CPE Modemsonly through the BWA BTS Modem.

The upstream channel supports multiple active transmitters (BWA CPE Modems) and one receiver (the BWA BTS Modem). Time in the upstream channel is slotted, providing for Time Division Multiple Access at regulated time ticks. The BWA BTS Modem provides the time reference and controls the allowed usage for each interval. Intervals (Time Slots) may be granted for transmissions by particular BWA CPE Modems, or for contention by all BWA CPE Modems. BWA CPE Modems may contend to request transmission time. To a limited extent, BWA CPE Modems may also contend to transmit actual data. In both cases, collisions can occur and retries are used. The MAC-sublayer messages from the BWA BTS Modem which direct the behaviour of the CPEs on the upstream channel, as well as messaging from the BWA CPE Modem to the BWA BTS Modem. Some of the protocol highlights include:

- Bandwidth allocation controlled by BWA BTS Modem.
- A stream of mini-slots in the upstream.
- Dynamic mix of contention- and reservation-based upstream transmit opportunities.
- Bandwidth efficiency through support of variable-length packets.
- Extensions provided for future support of ATM or other Data PDU.
- Class of service support.
- Extensions provided for security as well as virtual LANs at the Data Link layer.
- Support for a wide range of data rates.

IEEE 802.16 standards effort

IEEE 802.16 is currently working on PHY/MAC standards for BWA systems expected to be completed by January 2001. There are 2 proposals that have survived the stringent scoring procedures established by IEEE 802.16 (at the start, there were about 15 PHY and MAC proposals). Currently work (as of Jan.31, 2000) is underway attempting towards merging of these proposals. One proposal is based upon DOCSIS based PHY optimized for FDD operation (supported by more than 12 companies including Nortel Networks) while the other proposal is optimized for TDD operation (supported by 3 companies including Ensemble).

The DOCSIS based PHY proposal is an extension of ITU standards described in the last section. This PHY proposal supports both DVB (Digital Video Broadcasting) and DOCSIS based CPEs. The enhancements

that are under consideration include use of enhanced coding mechanisms e.g. turbo coding, adaptive modulation and error detection schemes.

The MAC proposal is based on DOCSIS 1.1 [5,6,7] that have additional features compared to DOCSIS 1.0 such as Quality of Service (QoS), fragmentation, concatenation, security enhancements (Baseline Privacy Plus), payload header compression and encryption support for multicast signaling. The specification also provides the necessary underlying services required to support large scale deployment of Voice over IP (VoIP) and other delay sensitive applications.

Summary

This paper presented a brief overview of standards activities related to BWA undertaken globally. In particular, the cable modem based BWA standards were detailed in this paper.

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REFERENCES

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[2] Draft Recommendation ITU-R F.BWA: Radio Transmission systems for Fixed Broadband Wireless Access (BWA) based on cable modem standards (Annex B of J.112), 1999

[3] ITU-T Recommendation J.112 "Transmission systems for interactive cable television services"

[4] ITU-T Recommendation J.83 "Digital multiprogramme systems for television, sound and data services for cable distribution"

[5] Data-over-Cable Service Interface Specifications (SP-RFv1.1-I02-990731)

[6] Data-over-Cable Interface Specifications, Security System interface specification, SP-SSI-I01-970506

[7 Baseline Privacy Plus Interface Specification, SP-BPI+-I03-991105