Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Nokia proposal for the 802.16 PHY**
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Re:	This contribution is submitted in response to call for contributions from the IEEE 802.16 chair on Sept. 22nd, 1999 for submission on PHY proposals for BWA.
Abstract	This proposal contains solutions for the 802.16 PHY layer to make low cost terminals possible and thus to address the small-business as well as the residential market.
Purpose	Proposal to serve as a baseline for the 802.16 PHY standard.
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Release	
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Proposal of Nokia for the 802.16 PHY

Introduction

Broadband wireless access (BWA) technology has to compete with a variety of other technologies, some of which already are available and others that will come in the near future. Examples of competing technologies are T1 lines, ISDN, xDSL pairs and HFC networks.

For 802.16 to be successful it must be able to offer a rich set of services on low cost terminals to residential and small business customers. In order for BWA to get a large market share it is important to have an interoperability standard.

Nokia sees the high frequency radio technology potentially expensive. This paper outlines the most important functions of the physical layer of 802.16 keeping in mind the cost factor. It is assumed that within a short time period the products made according to 802.16 standard will be economical.

Overview

This section describes functions of the PHY layer. The main solutions in our proposal are the following:

- Duplex

  In order to have low cost terminals the microwave diplex filter should be replaced by a switch. This will implies that terminals cannot transmit and receive simultaneously.

  - Terminals use half duplex FDD or TDD
  - BTS uses full duplex FDD or TDD
- Multiple access method is TDMA.
- The preferred frequency bands are in the range 10 – 60 GHz
- Base Transceiver Station (BTS) uses multiple sectors
- Support for future use of smart antennas
- The channel width is 20 – 30 MHz
- Variable high capacity single carrier modulation in the down link
- Robust constant envelope modulation scheme in the uplink

Duplex Scheme

For BWA to be successful low cost equipment is a must because the price will highly affect the deployment. There are basically two different duplex schemes that define how bidirectional traffic is handled.

Time Division Duplex (TDD) uses the same frequency band for transmission in both the upstream and the downstream direction. Within a time frame the direction of transmission is switched alternatively between down link and uplink.

Frequency Division Duplex (FDD) uses two separate frequency bands for the upstream and the downstream transmissions. FDD can work in both full duplex and half duplex modes. Full duplex FDD needs a diplex filter to separate the received waveform from the transmitted waveform. Half duplex FDD, which does not send and receive at same time, needs only a switch for TX/RX separation.

We propose that the terminals work in half duplex FDD (H-FDD) mode or TDD mode and the BTS in full duplex FDD or TDD modes. This will make possible low cost terminals because they do not need an expensive diplex filter. TDD also has the advantage of better supporting the dynamic division of the air interface capacity between the up- and down link.

Multiple access

The multiple access scheme to be chosen for 802.16 must fulfill a variety of requirements in order to serve both business users and residential users. In particular it must be capable of

- Efficient statistical multiplexing.

  The average bitrate can be relatively low but there is a need for a high peak rate in order to guarantee quality of service. Multiplexing gain in order of > 100 is needed
- Efficient use of available spectrum
  - Support high number of users
  - Support of high bitrates
- Good coverage
- Low cost implementation
  - Signal processing
  - Power amplifier

TDMA, FDMA and CDMA access schemes can be potential candidates. FDMAs lack of statistical multiplexing makes it very difficult to apply in a standard like this. CDMAs baseband complexity and RF linearity requirements makes it also difficult to apply in systems where low cost is important. TDMA seems to be the only access scheme that best fulfills the above requirements. It is therefore proposed that TDMA shall be the access scheme in the 802.16 standard

Modulation

The following observations are important to make when discussing the modulation schemes:

- Modulation should always be discussed together with channel coding. The modulation scheme is the prime factor which affects capacity. Modulation scheme, channel coding and carrier to noise (C/N) ratio will together determine the limits of the capacity.
- A higher capacity in the down link than in the uplink is anticipated. In particular Internet access traffic to the terminals will have a very asymmetric profile.
- To ensure a high availability (99.99%) a large fade margin is needed. This fade margin can be utilized to dynamically change the modulations schemes to increase the capacity. By monitoring the C/N value the modulation can be changed on a burst to burst basis.
- The uplink modulator must be made economically in order to have low cost terminals. Special attention must be paid to the power amplifier.
- The modulation scheme should work optimally in the LMDS frequency bands (Line-of-Sight condition).

Based on the above considerations we propose that single carrier modulation will be used in the down- and uplink in the following way:

Downlink

Trellis coded modulation (TCM) combines error correction and modulation without increasing the channel bandwidth. With TCM a coding gain of more than 4 dB is easily achieved compared to corresponding QAM modulation. The coding is additionally improved with an outer Reed-Solomon code. This will lead to increased coverage and capacity. The following modulation schemes are the preferred for the downlink: TCM-8, TCM-32 and TCM-128. An excess bandwidth of 0.2-0.4 is considered. It is noted that the higher modulation schemes will have a larger peak-to-average ratio and will need a linear power amplifier. It is however also noted that the BTS is not as cost sensitive as the terminals and a more expensive power amplifier can be afforded as the price eventually will be shared between many terminals.

Uplink

The uplink needs a modulation scheme that can use a low cost power amplifier. It is therefore proposed that the uplink modulation method should be a constant envelope type of modulation where the amplifier can be driven into saturation. Other important factors are spectral efficiency, and implementation complexity. Tamed frequency modulation (TFM) or some form of constant envelope QPSK is proposed as the modulation scheme for the uplink.

There might be users needing a high capacity in the uplink as well. In this case more expensive high grade terminals with TCM modulation could also be used.

Channel Coding

In order to meet the BER requirements under moderate C/N conditions channel coding is mandatory. Channel coding increases both coverage and capacity and is an important part of any digital communication system. There are two main types of coding schemes: block coding and convolution coding. Block coding operates on finite length blocks and convolutional code works often in a continues manner. A combination of these are proposed for the down link. Reed-Solomon forward error code is proposed as the outer code because of its excellent distance properties and moderate implementation complexity. In the downlink the inner code is inherent in the TCM modulation. There is no overhead in using TCM as it preserves the signal bandwidth. RS-code is optimal for correcting burst errors that might come from the TCM demodulator.

The uplink uses robust modulation and needs just a Reed-Solomon block code.

Benefits of the proposed PHY

The driving force behind the proposal is simplicity and low cost. Half duplex FDD and TDD are seen as way of dramatically decrease the cost of the terminals. TDMA is proposed for its ability to fulfill the requirements of statistical multiplexing. Variable modulation in the downlink gives a higher coverage with low C/N and a higher capacity with high C/N. Tamed frequency modulation (TFM) makes possible low cost solutions for the terminals.

Relation to existing standards

In Europe ETSI BRAN HIPERACCESS develops a similar standard for wireless broadband access networks. Efforts should be made to harmonize 802.16 and HIPERACCESS. This will lead to higher volumes and decreased manufacturing costs.
It is noted that the air interface is different from cable and existing cable standards are difficult to directly utilize here mainly because of different interference conditions and lack of TDD mode.

Statement of intellectual property rights

Nokia may have IPR in the standards under consideration. If Nokia has any applicable essential patents, it will comply with the IEEE IPR rules regarding disclosure and licensing.

Conclusions

This paper defines the basic properties of the PHY layer for 802.16. It is believed that the solutions fulfill the requirements of operators and different types of end customers.