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WiMAX

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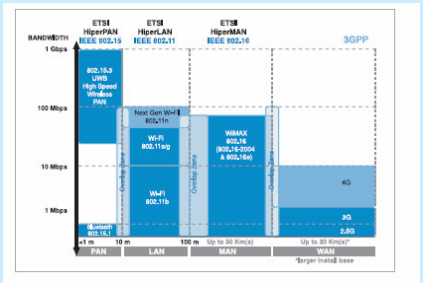
Outline

1. Background for broadband wireless technologies

- The IEEE and ETSI standards are interoperable and focus primarly on wireless packet-based networking
- The 3GPP standard focuses on cellular and third-generation mobile systems



1. Background for broadband wireless technologies

- UWB - Ultra Wide Band
  - high speed wireless personal area network
- Wi-Fi - Wireless fidelity
  - wireless technology for indoor environments (WLANs)
  - broader range that WPANs
- WiMAX - Worldwide Interoperability for Microwave Access
  - Wireless Metropolitan Area Networks (WMANs)
  - for outdoor coverage in LOS and NLOS environments
  - fixed and mobile standards
- 3G - Third generation
  - Wireless Wide Area Networks (WWANs) are the broadest range wireless networks
  - high speed data transmission and greater voice capacity for mobile users

2. What is WiMAX?

- WiMAX is an IEEE802.16/ETSI HiperMAN based certificate for equipments fullfilling the interoperability requirements set by WiMAX Forum.
- WiMAX Forum comprises of industry leaders who are committed to the open interoperability of all products used for broadband wireless access.
- The technique or technology behind the standards is often referred as WiMAX.

2. What is WiMAX?

- WiMAX is thus a Broadband Wireless Access (BWA) technique.
- WiMAX offers fast broadband connections over long distances.
- The interoperability between different vendor's products is the most important factor when comparing to other techniques.

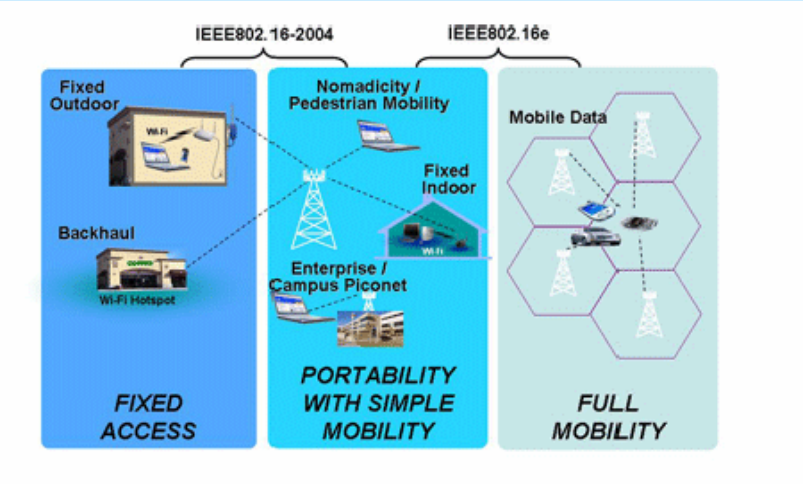
3. The IEEE 802.16 standards

- The **IEEE 802.16** standard family
  - broadband wireless wideband internet connection
  - wider coverage than any wired or wireless connections before
- Wireless systems have the capacity to address broad geographic areas without the expensive wired infrastucture.
- For example, a study [1] made in University of Oulu states that WiMAX is clearly more costeffective solution for providing broadband internet connection in Kainuu than xDSL

3. The IEEE 802.16 standards

- **802.16,** published in April 2002
  - A set of air interfaces on a common MAC protocol
  - Adresses frequencies 10 to 66 GHz
  - Single carrier (SC) and only LOS
- **802.16a,** published in January 2003
  - A completed amendment that extends the physical layer to the 2 to 11GHz both licenced and licence-exempt frequencies.
  - SC, 256 point FFT OFDM and 2048 point FFT OFDMA
  - LOS and NLOS
- **802.16-2004,** published in July 2004
  - Revises and replaces **802.16**, **802.16a**, and **802.16REVd**.
  - This announcement marks a significant milestone in the development of future WiMax technology
  - P802.16-2004/Cor1 published on 8.11.2005
- **802.16e,** Draft 12 was approved 7.12.2005 [2]
  - Extends the **802.16a** standard for portability (mobile clients).

3. The IEEE 802.16 standards



4. WiMAX deployment types

- To address the challenges associated with traditional wired access deployment types such as:
- Backhaul
  - point-to-point
- Last mile
  - point-to-multipoint
- Large-area coverage
  - uses base-stations, subscriber stations and Wi-Fi (mesh) solutions to cover a large area. (Hot spots)

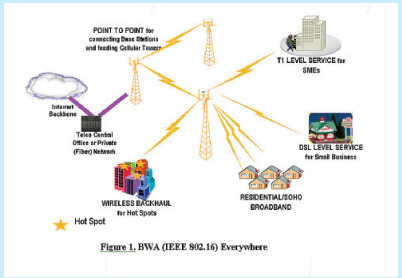


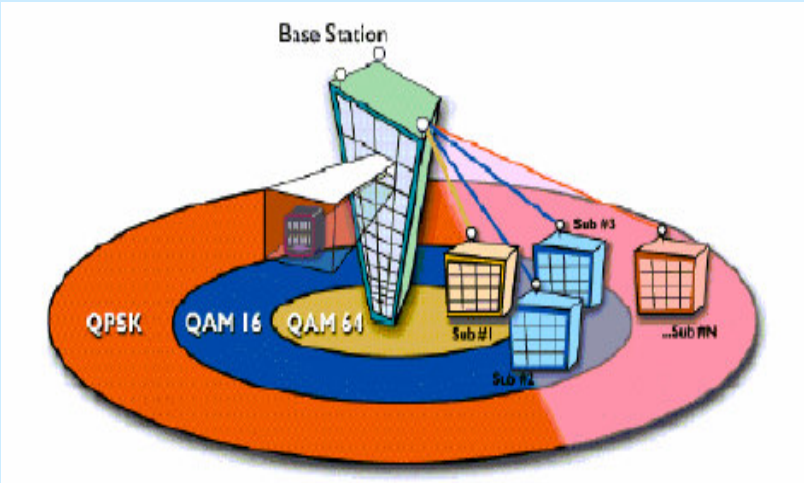
Figure 1. BWA (IEEE 802.16) Everywhere

5. WiMAX promises

- The maximum values are 50km coverage under LOS and 8km under NLOS conditions.
- In practice probably 7-10km coverage is possible in fixed bradband accesses and 200m-1km in portable devices [3].
- The table below presents the rates (Mbps) for a given channel bandwidth.
- These rates are then devided between the users in the cell.

Modulation → Code Rate	QPSK →1/2	QPSK →3/4	16 QAM →1/2	16 QAM →3/4	64 QAM →2/3	64 QAM →3/4
1,75 MHz	1,04	2,18	2,91	4,36	5,94	6,55
3,5 MHz	2,08	4,37	5,82	8,73	11,88	13,09
7,0 MHz	4,15	8,73	11,64	17,45	23,75	26,18
10,0 MHz	8,31	12,47	16,63	24,94	33,25	37,40
20,0 MHz	16,62	24,94	33,25	49,87	66,49	74,81

5. WiMAX promises

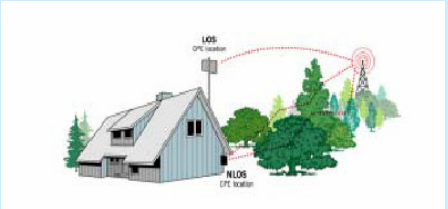


6. WiMAX for the NLOS environment

- WiMAX is the first wireless solution utilizing NLOS signal propagation.
- In a NLOS link, a signal reaches the receiver through reflections, scattering, and diffractions.
- There are no strong signal path as in LOS or NrLOS.
- The multipath phenomena can also cause the polarization of the signal to be changed.
- Using polarization as a means of frequency re-use can be problematic in NLOS.

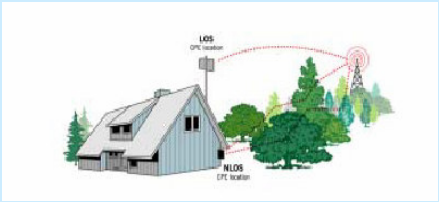
6. WiMAX for the NLOS environment

- NLOS relaxes the requirements of the antenna heigth.
- Lowering the antenna is advantageous to reduce the co-channel interference between adjacent cell sites.
- It is a benefit for large-scale contiguous cellular deployments where frequency re-use is critical.
- NLOS technology also reduces installation expenses of the premise equipment (CPE) installation



6. WiMAX for the NLOS environment

- The NLOS technology and the enhanced features in WiMAX make it possible to use indoor CPEs.
- This has two main challenges;
  - overcoming the building penetration losses
  - covering reasonable distances with the lower transmit powers and antenna gains that are usually associated with indoor CPEs.



7. NLOS Technology Solutions

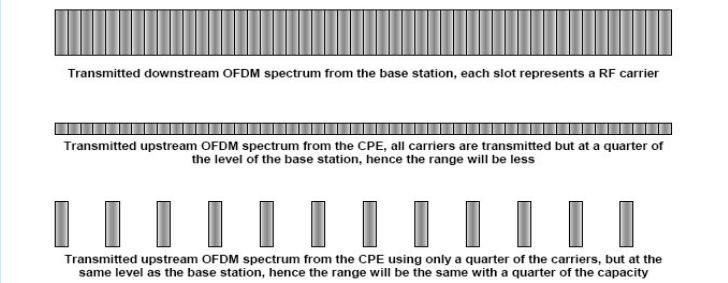
- OFDM technology
- Sub-Channelization
- Directional antennas
- Transmit and receive diversity
- Adaptive modulation
- Error correction techniques
- Power control

7. NLOS Technology Solutions, OFDM

- The WiMAX OFDM waveform offers the advantage of being able to operate with the larger delay spread of the NLOS environment.
- By virtue of the OFDM symbol time and use of a cyclic prefix, the OFDM waveform eliminates the inter-symbol interference (ISI) problems and the complexities of adaptive equalization.
- Because the OFDM waveform is composed of multiple narrowband orthogonal carriers, selective fading is localized to a subset of carriers that are relatively easy to equalise.

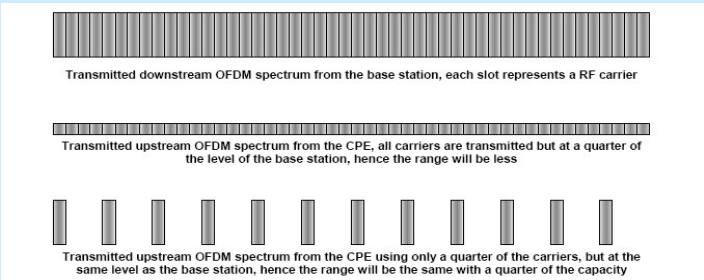
7. NLOS Technology Solutions, sub channelization

- Sub channeling concentrates the transmit power into fewer OFDM carriers.
- The increases in the system gain can be used
  - to extend the reach of the system
  - to overcome the building penetration losses
  - and/or to reduce the power consumption of the CPE



7. NLOS Technology Solutions, sub channelization

- Sub channelization is optional in the uplink.
- Regulatory restrictions and the need for cost effective CPEs, typically cause the link budget to be asymmetrical.
- Asymmetric link budget causes the system range to be up link limited.
- Sub channeling enables the link budget to be balanced.



7. NLOS Technology Solutions, AAS

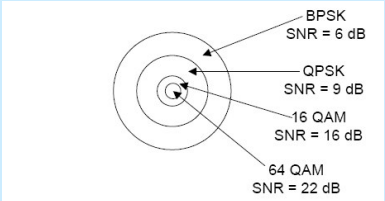
- Adaptive antenna systems (AAS) are an optional part of the 802.16 standard
- Directional antennas increase the fade margin by adding more gain.
- Delay spread further reduced at both the Base Station and CPE.
- The antenna pattern suppresses any multi-path signals or co-channel interference that arrive in the sidelobes and backlobes.
- Adaptive antenna systems are considered to be future developments that could eventually improve the spectrum re-use and capacity of a WiMAX network.

7. NLOS Technology Solutions, Diversity

- Diversity is also an optional feature in WiMAX.
- The WiMAX transmit diversity option uses space time coding to provide transmit source independence; this reduces the fade margin requirement and combats interference.
- For receive diversity, various combining techniques exist to improve the availability of the system.
  - For instance, maximum ratio combining (MRC) with two branches
- Diversity has proven to be an effective tool for coping with the challenges of NLOS propagation.

7. NLOS Technology Solutions, Adaptive modulation

- The key feature of adaptive modulation is that it increases the range that a higher modulation scheme can be used over, since the system can flex to the actual fading conditions, as opposed to having a fixed scheme that is budgeted for the worst case conditions.
- This feature allows the system to overcome time-selective fading.



Relative cell radii for adaptive modulation

7. NLOS Technology Solutions, Error correction

- Strong Reed Solomon FEC, convolutional encoding, and interleaving algorithms are used to detect and correct errors to improve throughput.
- Automatic repeat request (ARQ) is used to correct errors that cannot be corrected by the FEC, by having the errored information resent.

7. NLOS Technology Solutions, Power control

- The power level received at the base station is at a pre-determined level.
- The base station sends power control information to each of the CPEs
- In a dynamical changing fading environment this pre-determined performance level means that the CPE only transmits enough power to meet this requirement.
- The converse would be that the CPE transmit level is based on worst-case conditions.
- The uplink transmit power of in LOS conditions is approximately proportional to distance but for NLOS it is also heavily dependant on the clearance and obstructions.

8. Conclusions

- WiMAX technology can provide coverage in both LOS and NLOS conditions.
- NLOS has many implementation advantages that enable operators to deliver broadband data to a wide range of customers.
- For the first time, broadband wireless operators will be able to deploy standardized equipment with the right balance of cost and performance; choosing the appropriate set of features for their particular business model.
- WiMAX certificate then ensure the interoperability for the customer

Homework

In 2-11GHz band WiMAX is desinged both on licenced licence-exempt frequencies. Discuss and compare the two solutions. How they are for example able to overcome challenges like RF interference and infrastructure placement?

References

[1] Oulun yliopisto, Laajakaistayhteyksien tarjonta Kainuussa, 7.10.2004 http://kafi.tutka.net/fi_tied04/Laajakaistatarjontaraportti_Kainuu.pdf

[2] IEEE, Standards Assosiation, "IEEE 802.16e Mobile WirelessMAN (R) Standard is Official", 7.12.2005 http://standards.ieee.org/announcements/pr_p80216.html

[3] Viestintävirasto, Langattomat laajakaistaratkaisut, 20.6.2005

[4] Wave-Report, "IEEE 802.16 Tutorial", http://www.wave-report.com/tutorials/ieee80216.htm, page updated 30.5.2005

[5] Intel, "Deploying License-Exempt WiMAX Solutions", White papers, Intel 2005

[6] WiMAX Forum, "IEEE 802.16a Standard and WiMAX Igniting Broadband Wireless Access" White papers,

[7] Intel, "Understanding Wi-Fi and WiMAX as Metro-Access Solutions", White papers Wi-Fi and WiMAX Solutions 2004