WWRF Briefings 2004

High Throughput WLAN/WPAN

Gerhard Fettweis, Ernesto Zimmermann – Vodafone Chair
Hervé Bonneville – Mitsubishi Electric
Wolfgang Schott – IBM Research
Karine Gosse, Marc de Courville – Motorola Labs

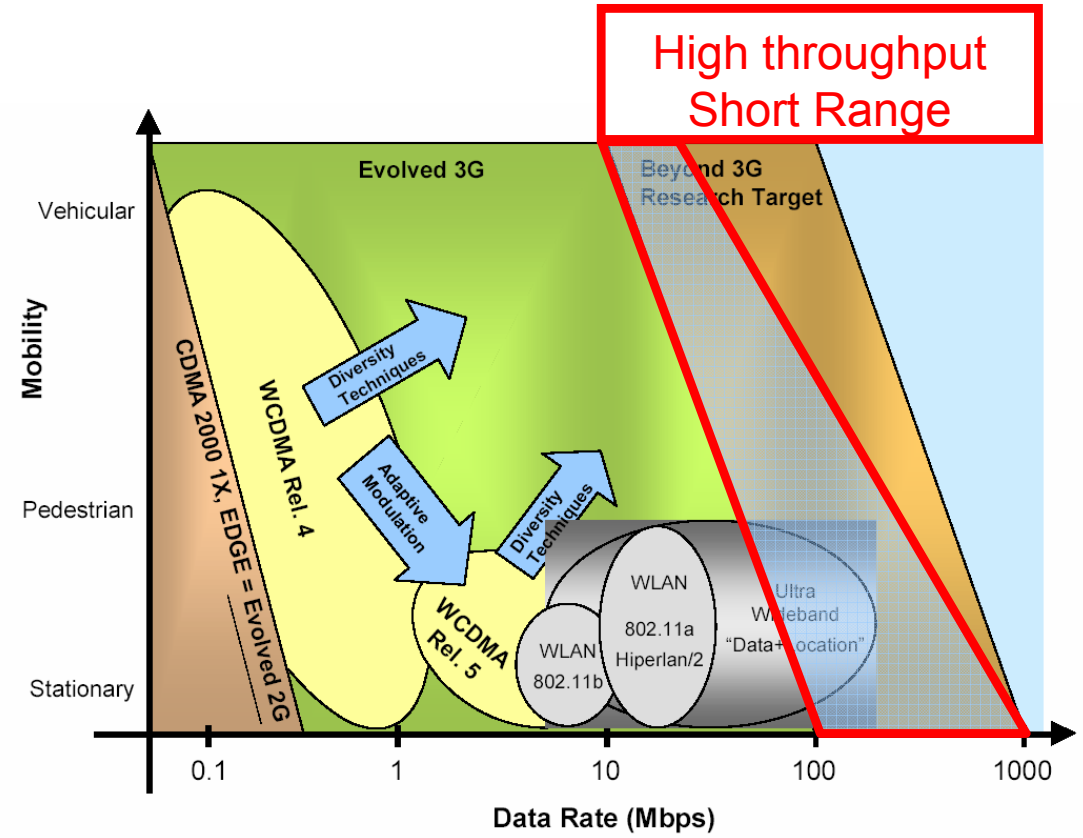
Wireless World Research Forum

Outline

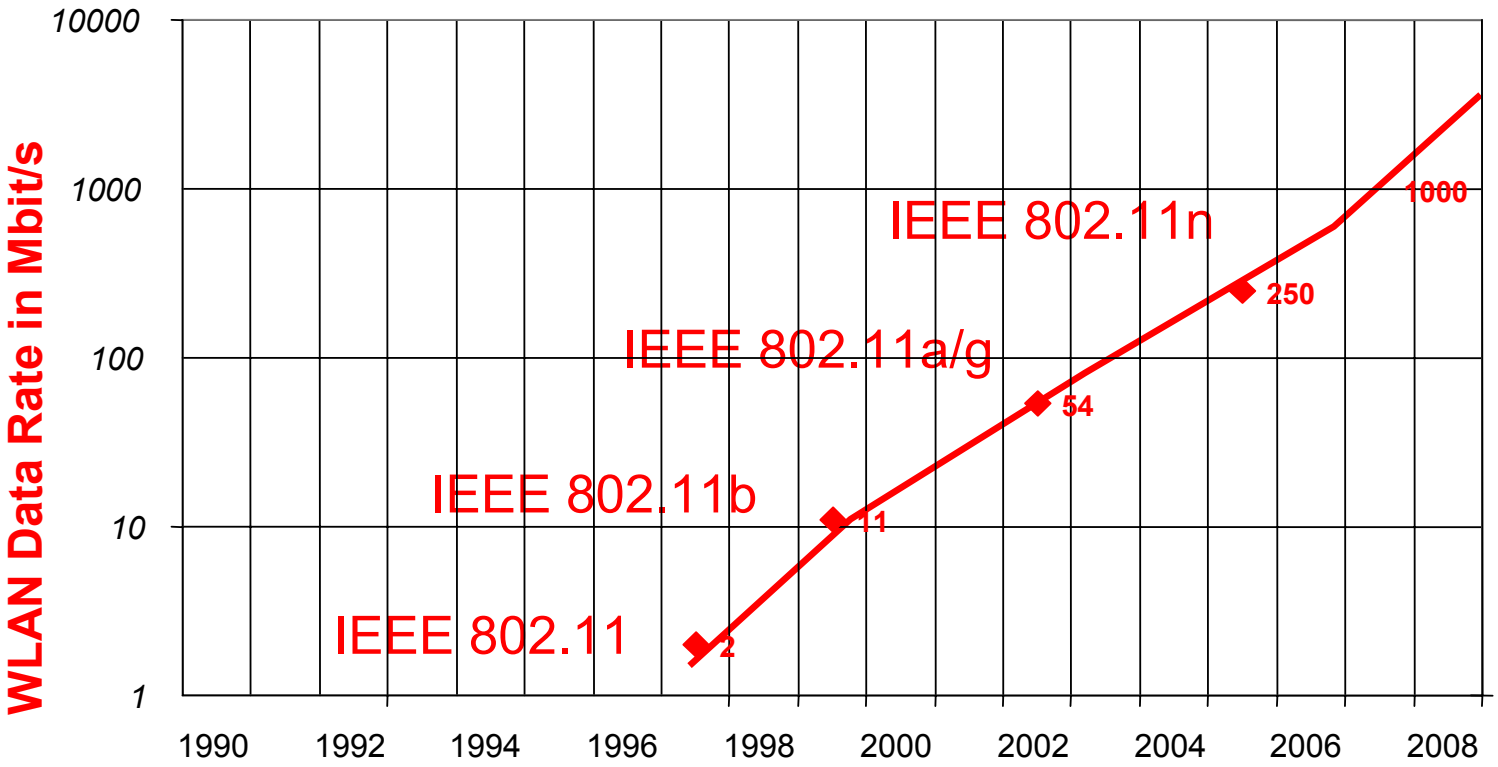
- Scope and Vision
- Deployment Scenarios
- Technical Requirements
- Key Challenges
- Standardization & Alliances
- Conclusions

Scope & Vision

- Scope
  - ⇒ **Short Range** Wireless
    - Range < 300m
    - Only local coverage
  - ⇒ **High throughput**
- Vision
  - ⇒ Wireless LAN/PAN replace Ethernet and wire based peripheral interfaces
  - ⇒ **"Wireless Gigabit"**
  - ⇒ 3 billion wireless users by 2015
- Objectives
  - ⇒ Identify **main drivers** and key **technological challenges**



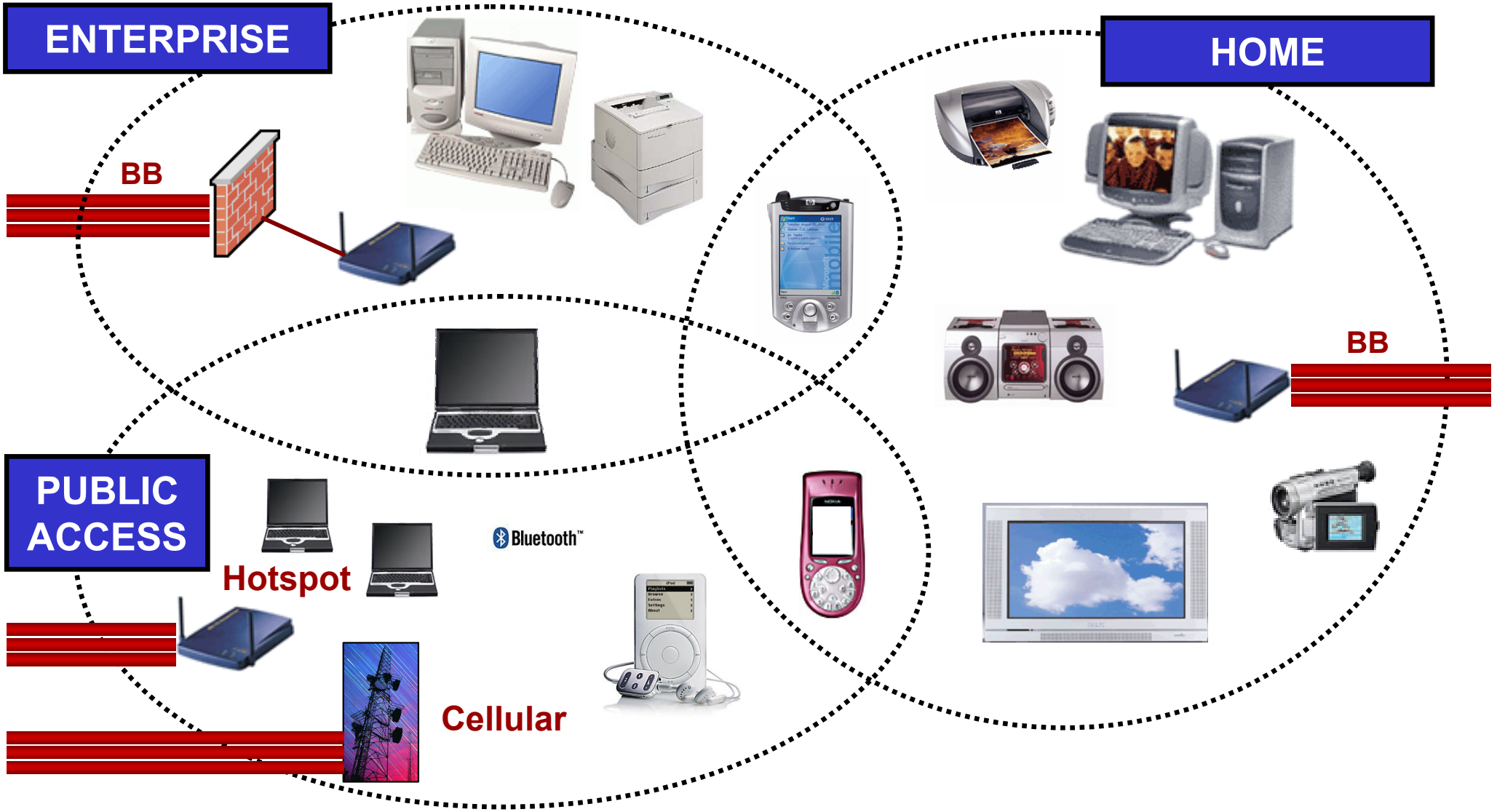
Roadmap – WLAN



- Gbit/s WLAN will happen around 2007/2008!
- We do not want to watch passively, but **contribute actively**.

Wireless World Research Forum

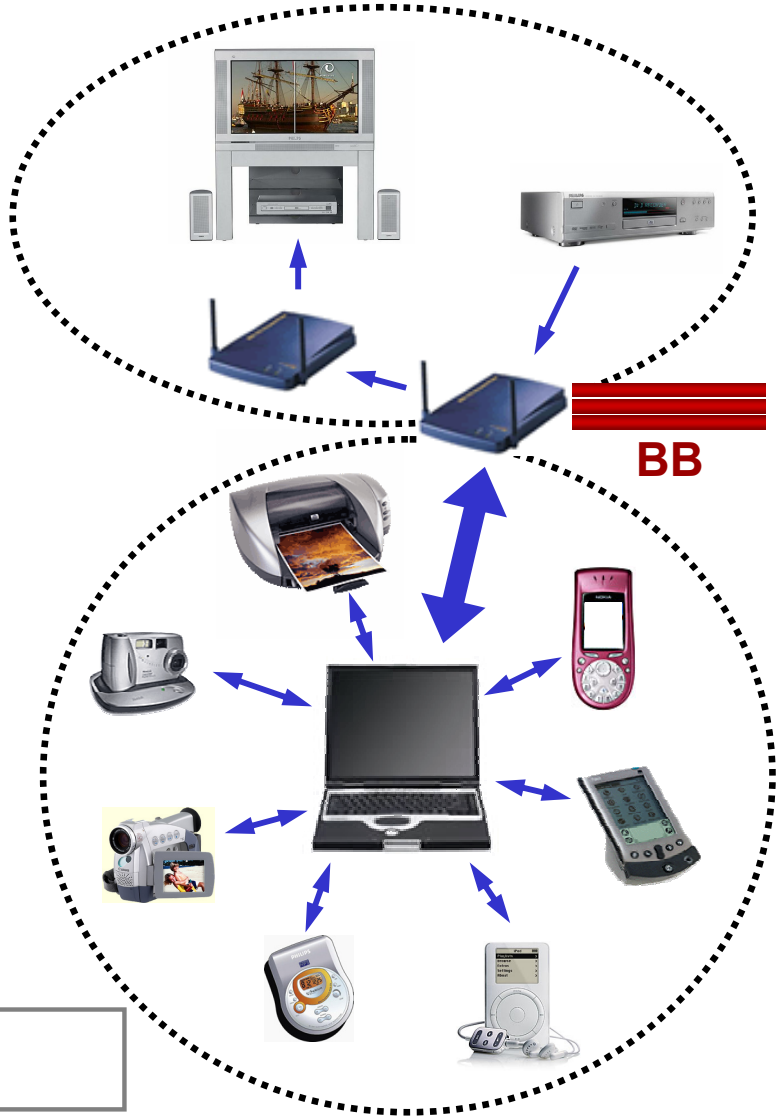
Deployment scenarios



Home environment

- Video streaming
  - ⇒ 20 MBit/s high quality
  - ⇒ x 3 hops
  - ⇒ + MAC overhead
  - ⇒ 100 MBits/s
- Internet download: 100 Mbit/s
- Audio (multi hop): 30 MBit/s
- Multiple users & applications
- Highly **bursty traffic**
- → **1 GBit/s required**

- **Self-configuration,** zero maintenance
- Ad-hoc and multi-hop capabilities



Key challenges: ease of use, robustness, QoS

Enterprise environment

- WLAN brought wireless interconnection to the office
  - ⇒ Work becomes detached from the desk
- 100baseT and 1000baseT are state-of-the-art
  - ⇒ Wireless Gigabit required to match enterprise demands
- VoIP and video conference systems necessary in enterprise environments
  - ⇒ QoS support is mandatory for wireless LAN in the office

Key challenges: throughput, quality of service, security/privacy

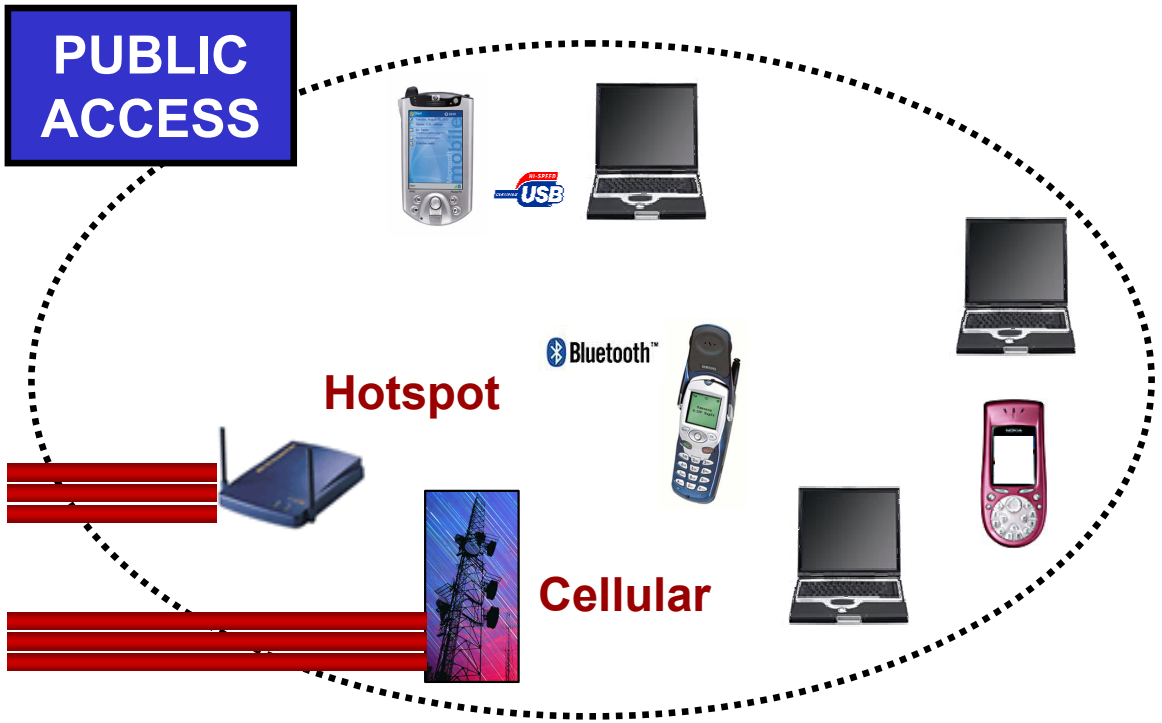
Public Access – HotSpot

- ISP provide decentralized internet (and intranet) access
- Hot spot coverage

- **High numbers of users** (e.g. up to 50 users at 80m²)
- Dramatic variation of maximum transmission bit rate during hand-off (vertical & horizontal)

→ **Highly flexible MAC** required

- **Differing service requirements**

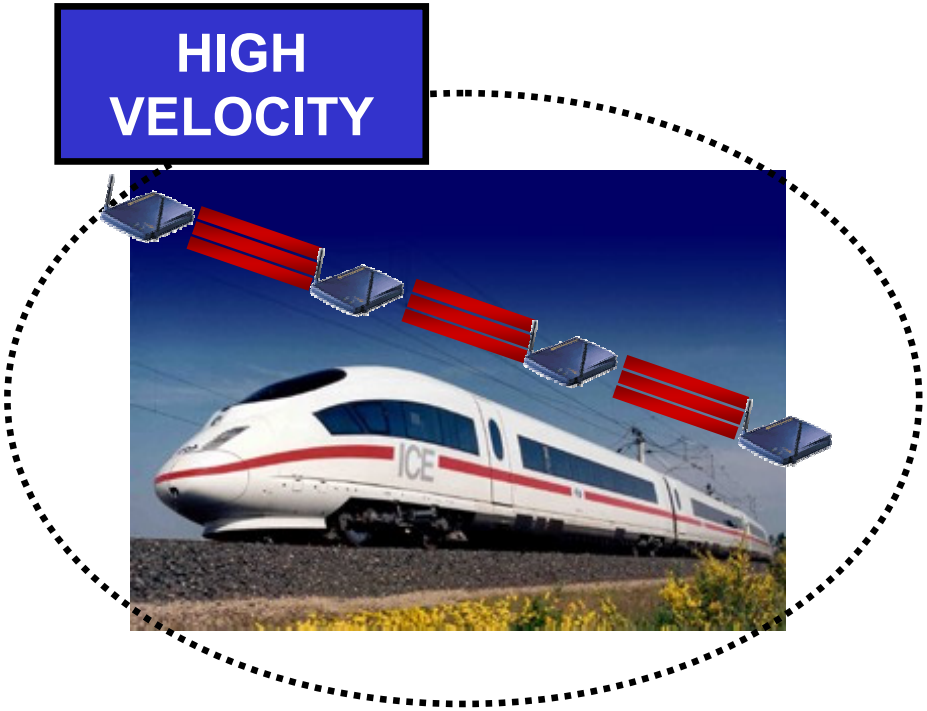


Key challenges: flexible high speed MAC, trade range vs. rate

Public Access – Trains and Highways

- Internet access in trains and cars
- Hot spot coverage along railway tracks and highways
- Access points in 100-300m distance

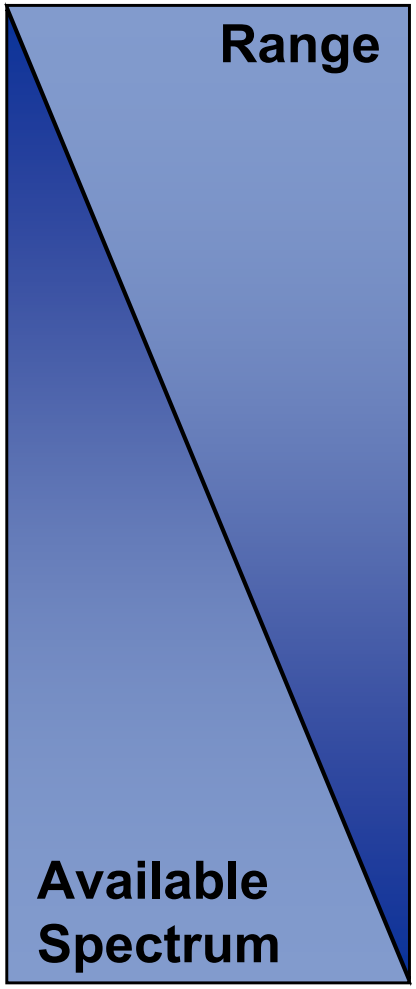
- LOS conditions
  - ⇒ High Doppler shift, low Doppler spread
  - ⇒ “Standard” hot spot solutions partly applicable



Key challenges: reliability, extremely fast hand-offs

Link Layer Options

- **“Conventional” Radio Communications**
  - ⇒ WG5 White Paper on MIMO-OFDM TDD Physical Layer
- **Ultra Wideband**
  - ⇒ WG5 White Paper on UWB: Technology and Future Perspectives
- **Millimeter Wave Communications**
  - ⇒ Upcoming WG5 WWRF Briefing
- **Optical Communications**
  - ⇒ WG5 White Paper on Optical Wireless Communications



Wireless World Research Forum

Main Challenges

- User data rates up to 100 MBit/s, peak data rate ~1 GBit/s
- Efficient and flexible high speed MAC with QoS
- Auto-configuration, ad-hoc and multi-hop capabilities
- Ease of integration in IP based backbone
- Coexistence with other systems

Technology Trends

- Baseband (focus on “conventional” radio communications)
  - ⇒ **Spatial** diversity and **multiplexing** techniques
  - ⇒ **Multi-carrier** modulation
  - ⇒ **Turbo principle** – iterative decoding, equalization, etc.
  - ⇒ Adaptive modulation and coding
- MAC
  - ⇒ Avoid short data burst to **minimize MAC overhead**
  - ⇒ **Superposed signaling** (separate high rate from low rate data)
  - ⇒ **QoS** support
- Cross-layer optimization
- Implementation issues
  - ⇒ PAPR reduction, baseband compensation for **“Dirty RF”**

Technology trends: Baseband techniques

"Wireless Gigabit"

- Large bandwidths
- High spectral efficiency

→ **OFDM to efficiently equalize frequency selective channel**

⇒ Enabler for high MAC granularity (OFDMA)
⇒ Preamble design – Guard interval vs. IOTA/OQAM
⇒ Implementation issues – PAPR, phase noise, etc.

→ **MIMO to attain high spectral efficiency**

⇒ Receiver processing – Linear, PIC, SIC, ML-like
⇒ Transmitter processing – Linear, THP, Lattice Precoding
⇒ Channel estimation – More pilots needed

→ **Iterative processing to minimize SNR requirements**

⇒ Turbo equalization, data aided channel estimation, etc.
⇒ Processing power vs. RF requirements trade-off

Technology trends: MAC issues

- **Efficiency (long PHY bursts ⇔ short MAC PDUs)**
  - ⇒ Fast ARQ, Hybrid ARQ
  - ⇒ New metrics for Link Adaptation
  - ⇒ Packet aggregation, superposed signaling
  - ⇒ Multi-dimensional resource allocation (Time, Frequency, Space)

- **Flexibility, centralized vs. distributed scheduling**
  - ⇒ Coordinated on-demand resource allocations
  - ⇒ Ensure high efficiency and low delay in high load regime
  - ⇒ Distributed allocation mechanisms (ad-hoc capabilities)

- **Self-configuration**
  - ⇒ Topology & coordination management
  - ⇒ Efficient routing schemes with good dynamic properties

Technology trends: Cross-layer optimization

Combined optimization throughout the network stack:

⇒ **PHY aware scheduling & routing**

- Channel conditions need to be taken into account at higher layers
- Multi user scheduling for throughput maximization (MIMO Multi User)

⇒ **Quality of Service mechanisms**

- Resource allocation based on service level agreements
- QoS aware error control

Wireless World Research Forum

Standardization

- IEEE 802.11a (WLAN)
  - ⇒ Data rates 54 MBit/s
  - ⇒ OFDM, carrier at 5 GHz
  - ⇒ PHY almost identical to ETSI/BRAN HiperLAN/2
- IEEE 802.11n (high throughput study group)
  - ⇒ Data rates 108-320 MBit/s (100 MBit/s on MAC SAP @ 20 MHz BW)
  - ⇒ MIMO-OFDM, carriers at 2.4, 5 GHz
- IEEE 802.15 (WPAN)
  - ⇒ Relevant subgroup: 802.15.3/3a (High rate, Alternative PHY)
  - ⇒ PHY data rates up to ~ 500 MBit/s
  - ⇒ Multi-band OFDM, DS-CDMA
  - ⇒ Carriers at 3.5 – 10 GHz, ultra wide bands

Wireless World Research Forum

Alliances

Wi-Fi Alliance

- ⇒ Promotion of IEEE 802.11 products
- ⇒ Aim: “enhance the user experience through product interoperability“
- ⇒ Internet/Intranet access in hot spots, home and office environment

Bluetooth Special Interest Group (SIG)

- ⇒ Promotion of IEEE 802.15 products
- ⇒ Aim: “Develop, publish and promote the preferred short-range wireless specification for connecting mobile products”
- ⇒ Low cost and low power

Conclusion

Main challenges

- Extremely high peak data rates
  - ⇒ High spectral efficiency requirements on PHY
  - ⇒ Efficient and flexible high speed MAC
  - ⇒ Cross-layer optimization
- Integration into B3G, coexistence with other systems

The realization “Wireless Gigabit” requires challenges on all layers of the network stack to be tackled – jointly.

References

WWRF documents

- WWRF WG5 White Paper “New Radio Interfaces for Short Range Communications”
- WWRF Book of Visions 2001: http://www.wireless-world-research.org/

Publications

- Karine Gosse *et al*., “The Evolution of 5 GHz WLAN Toward Higher Throughputs”, IEEE Wireless Communications Magazine, December 2003

Projects

- WINNER: http://www.ist-winner.org/
- BROADWAY: http://www.ist-broadway.org/
- Chinese FuTURE Project: http://future.863.org.cn/
- Wigwam: http://www.wigwam-project.com/

Standardization and Alliances

- IEEE 802.11,15,16,20: http://www.ieee802.org/
- ETSI BRAN HiperLAN/2: http://portal.etsi.org/bran/kta/Hiperlan/hiperlan2.asp
- ARIB MMAC: http://www.arib.or.jp/mmac/e/