Energy Efficiency Optimization for Future Wireless Broadband Networks

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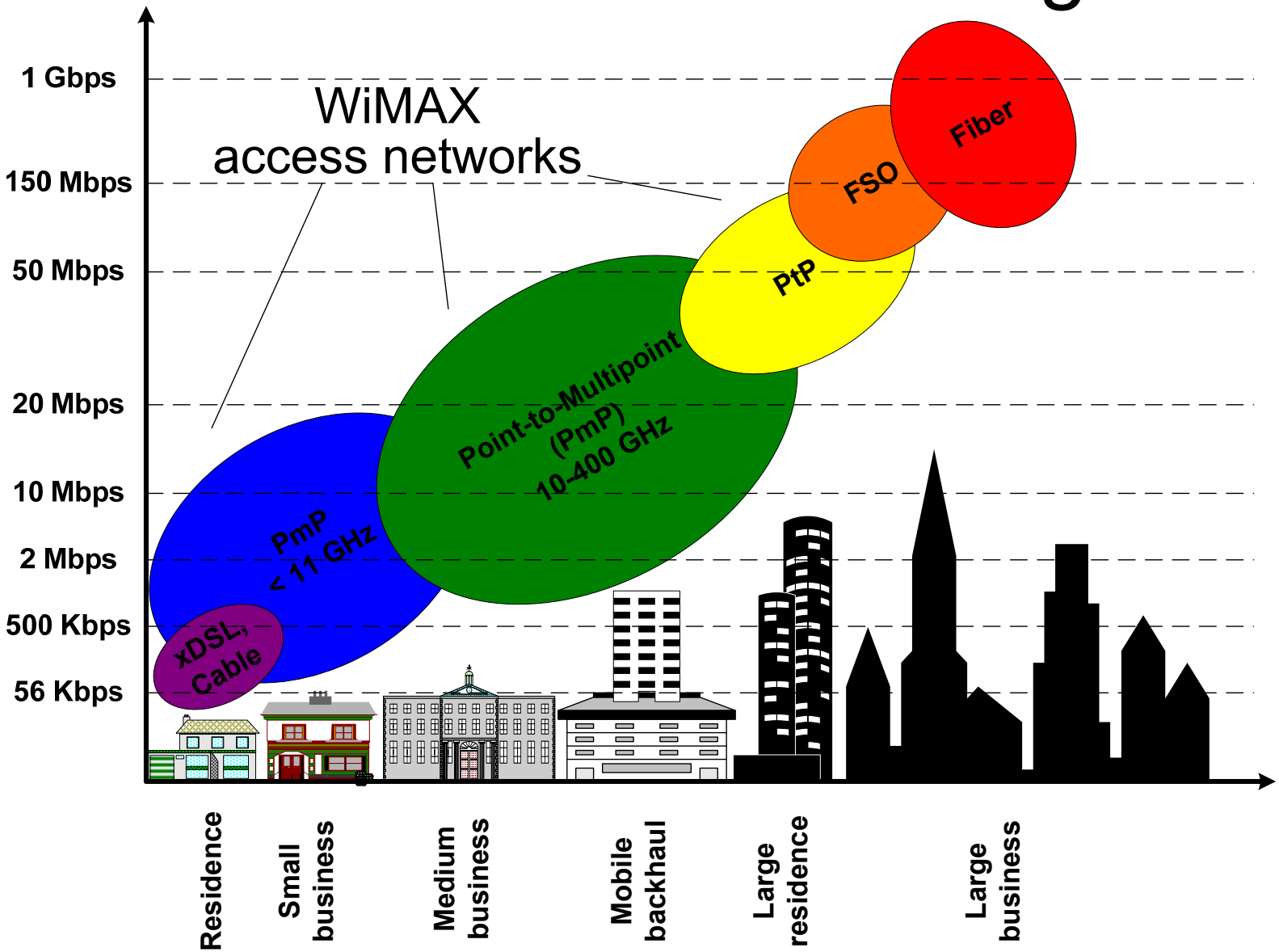
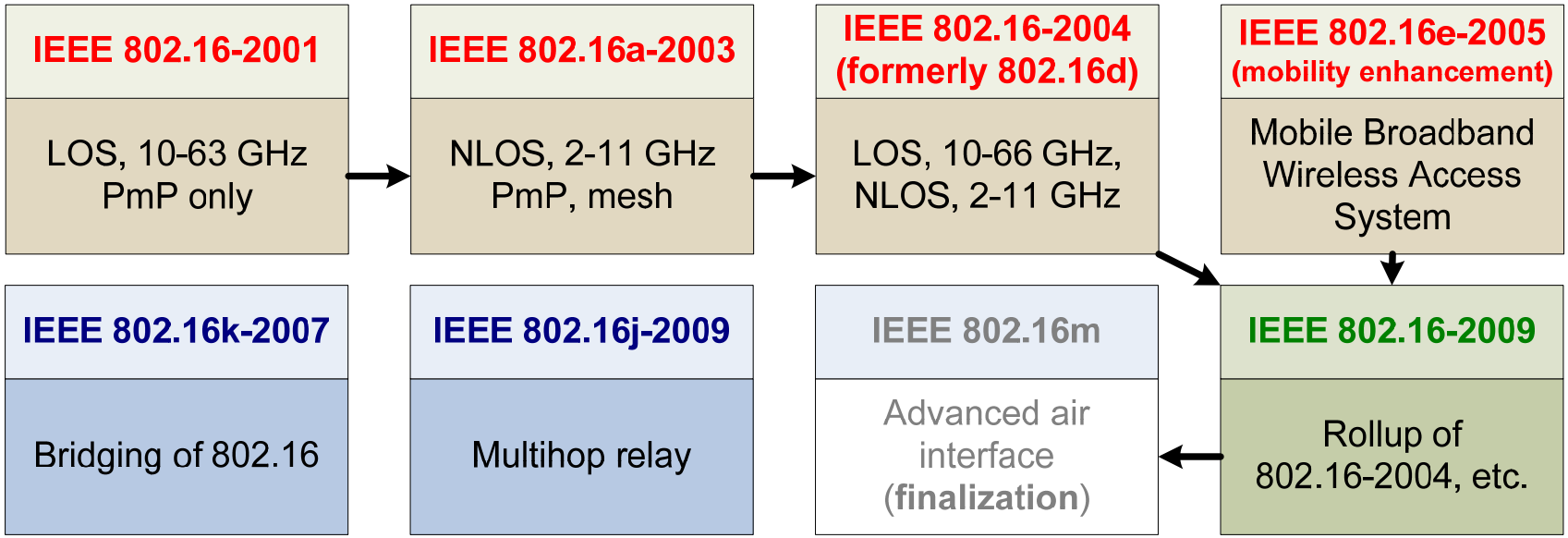
Session Agenda

- IEEE 802.16 in brief
- Energy efficient challenges
- Some initial work
- More research targets
- Plans for future

IEEE 802.16 Market Segment



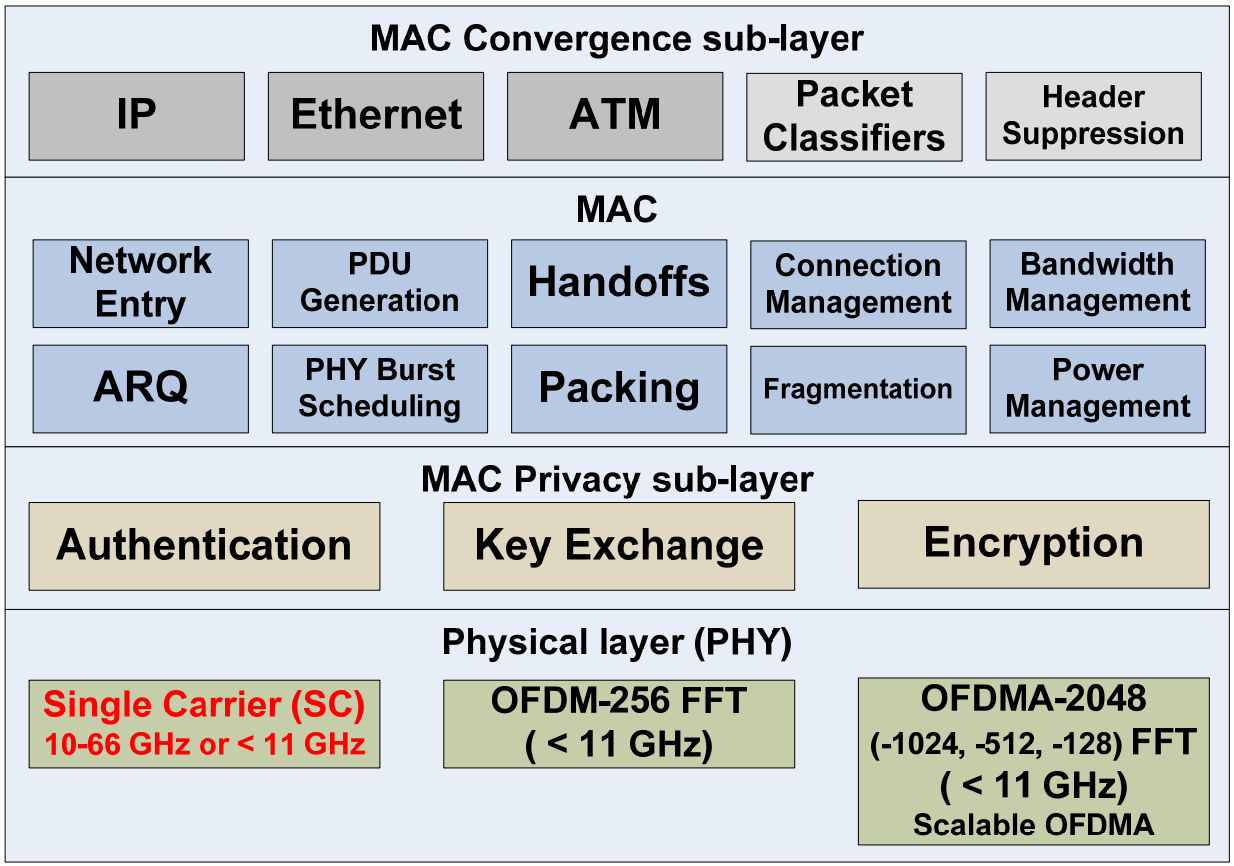
IEEE 802.16 Standard Evolution



IEEE 802.16m standard features

- Clients with **limited** battery life
- **Tight** QoS requirements

IEEE 802.16 Protocol Stack



- **Scalability**

MAC-inherent, ~1000 users

- **Performance**

Up to 70 Mbps

in IEEE 802.16-2004

- **Quality of Service**

Grant-request MAC,

delay guarantee

- **Range**

Adaptive PHY and MAC,

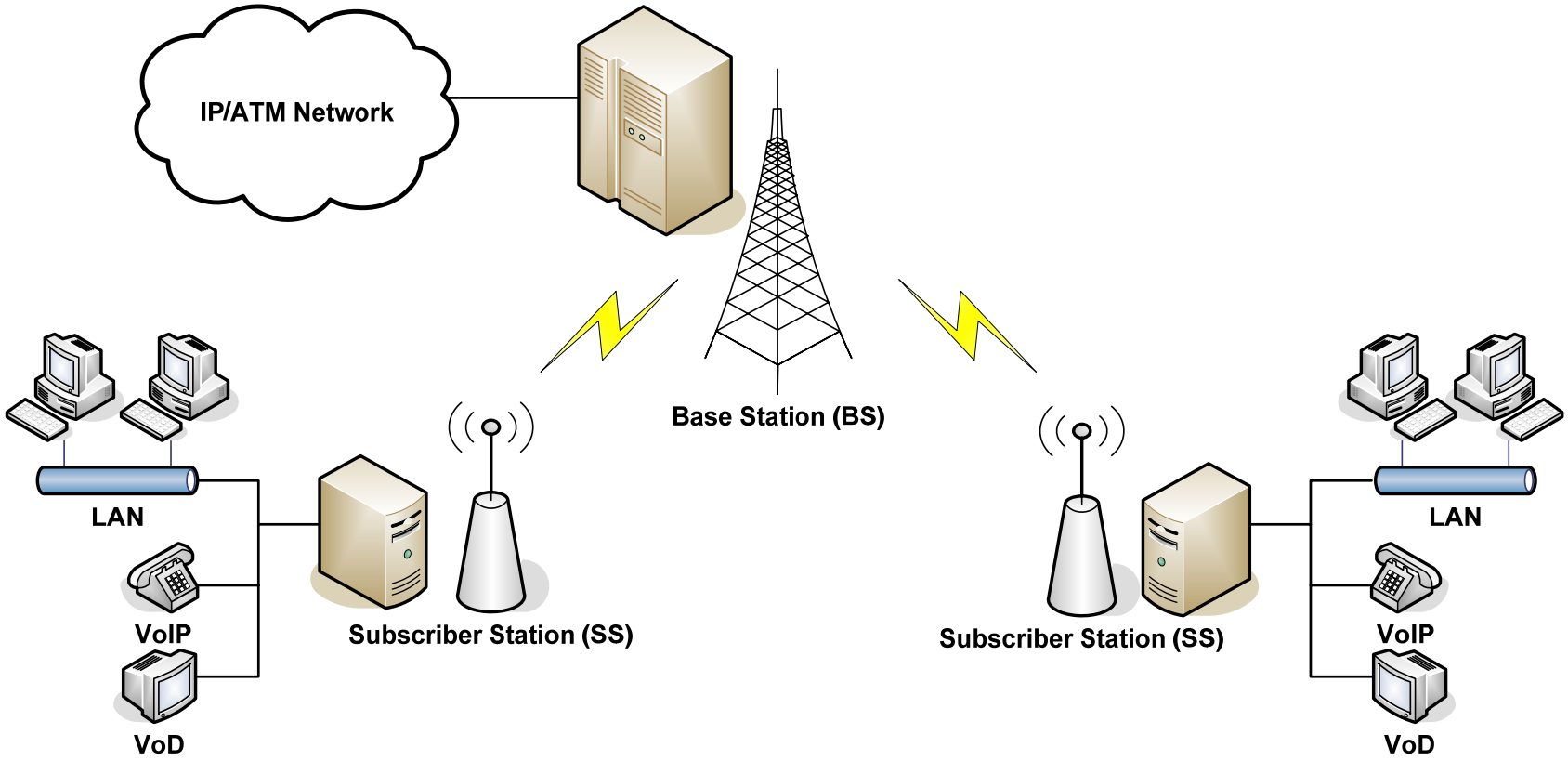
~10 km

- **Coverage**

Outdoor NLOS

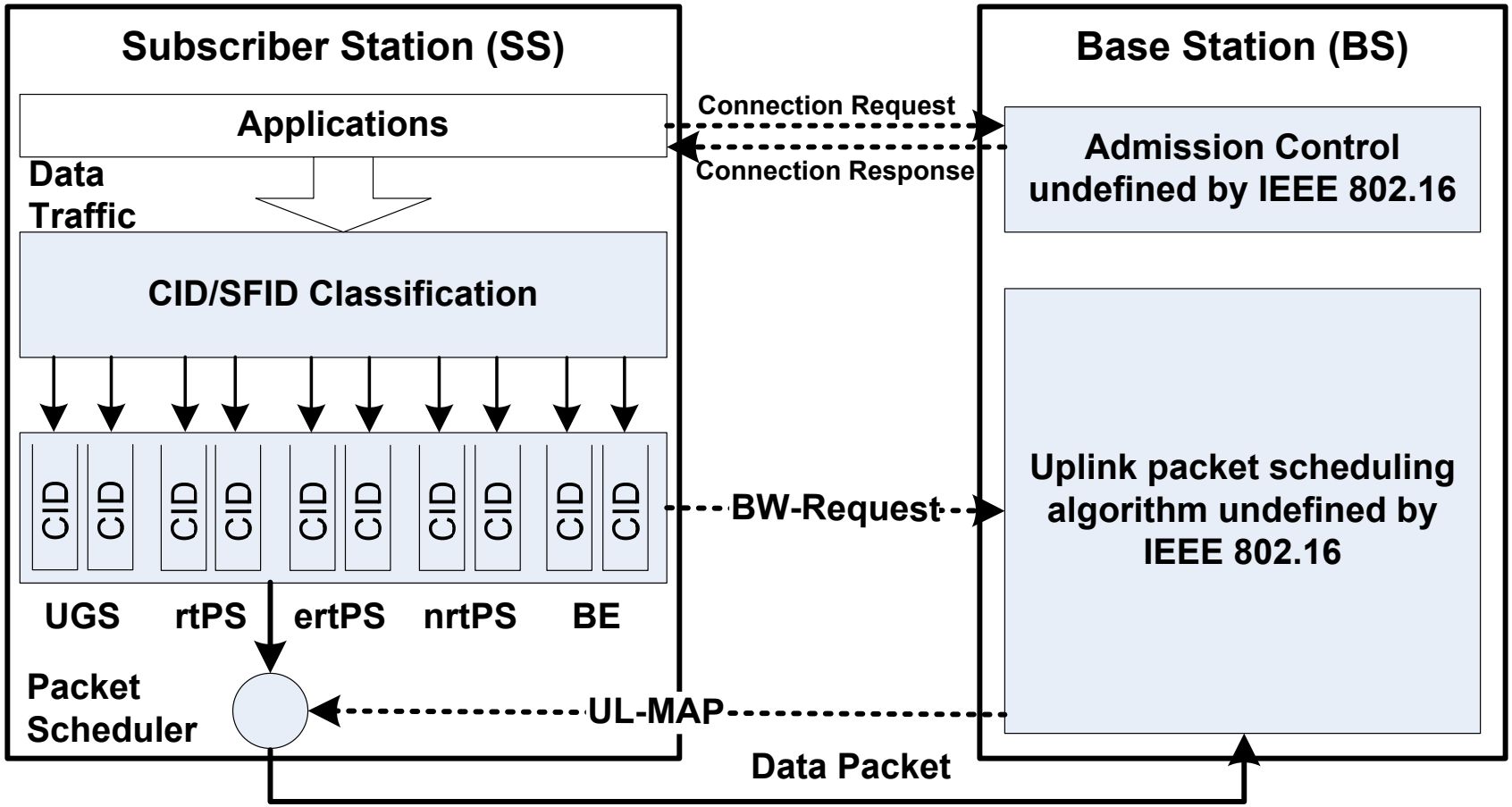
- **Security**

Basic IEEE 802.16 Architecture



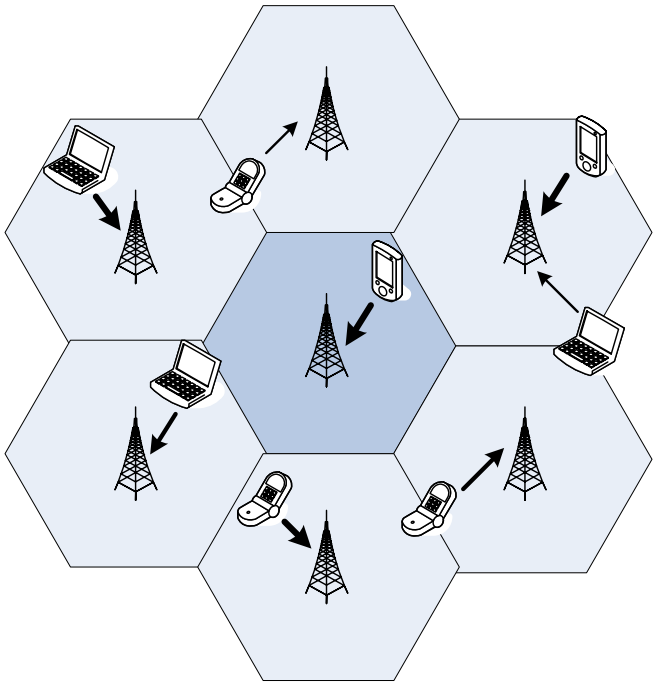
- **Centralized** and distributed operation modes
- Dynamic resource allocation
  - Bandwidth requesting
  - **Schedule** management
- Quality of service assurance for end clients

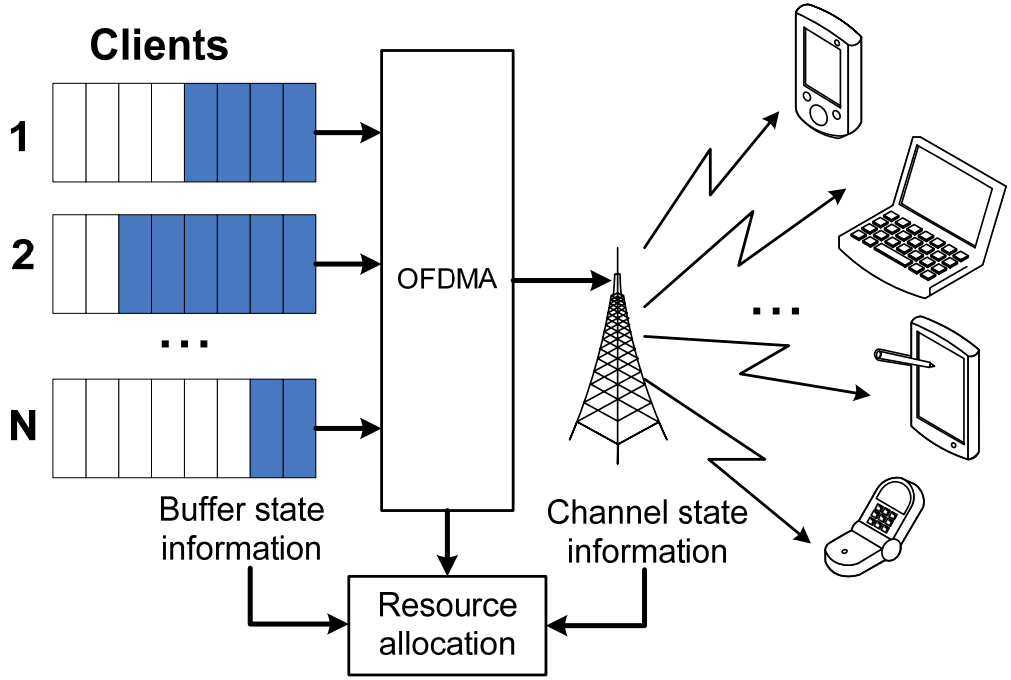
QoS Architecture of IEEE 802.16



Scheduling at BS is **challenging**

General Problem Formulation

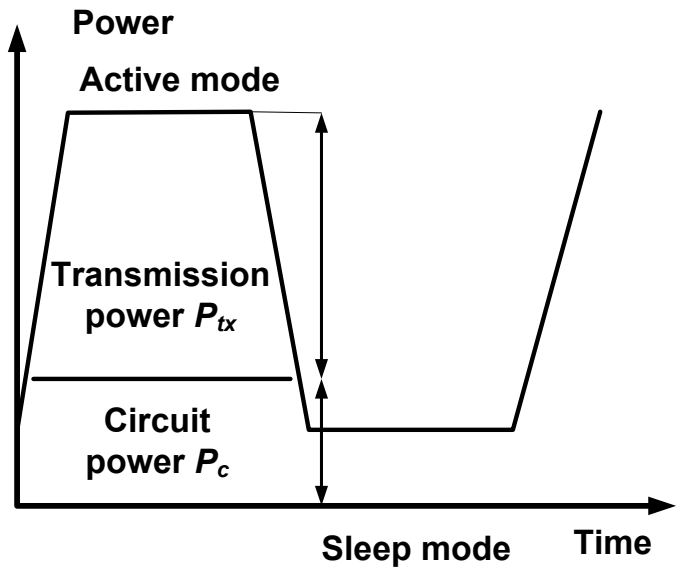


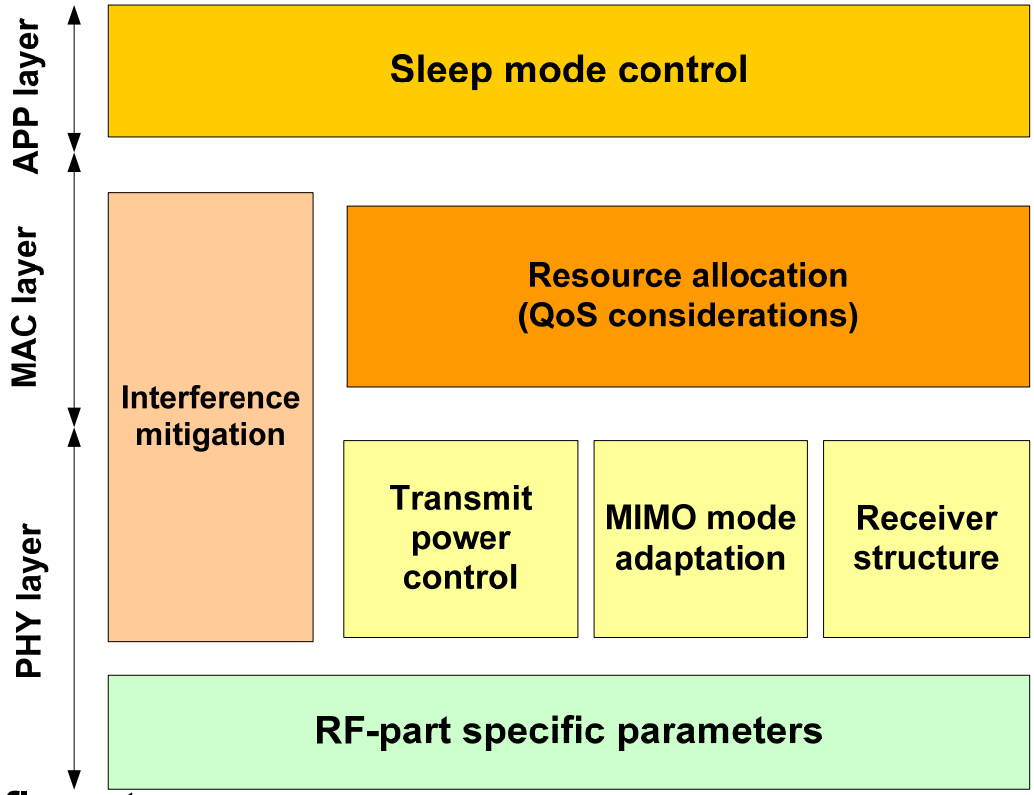


Goal: Energy efficiency **increase**. Control

- data rate and transmission power;
- resource allocation to clients;
- sleep mode operation [1]

System Features





Complex approach is required

- Quality of service and arrival flow type
- Scheduler algorithm
- Power control algorithm
- Inter-cell interference
- Client power profile
- Coexistence with other systems

Simplified Approach

$$C_i = B_i \log\left(1 + \frac{G_i P_{tx,i}}{N}\right)$$

Shannon's law consideration [2]

- **Linear** relation between transmission rate and bandwidth
- **Exponential** relation between transmission rate and power

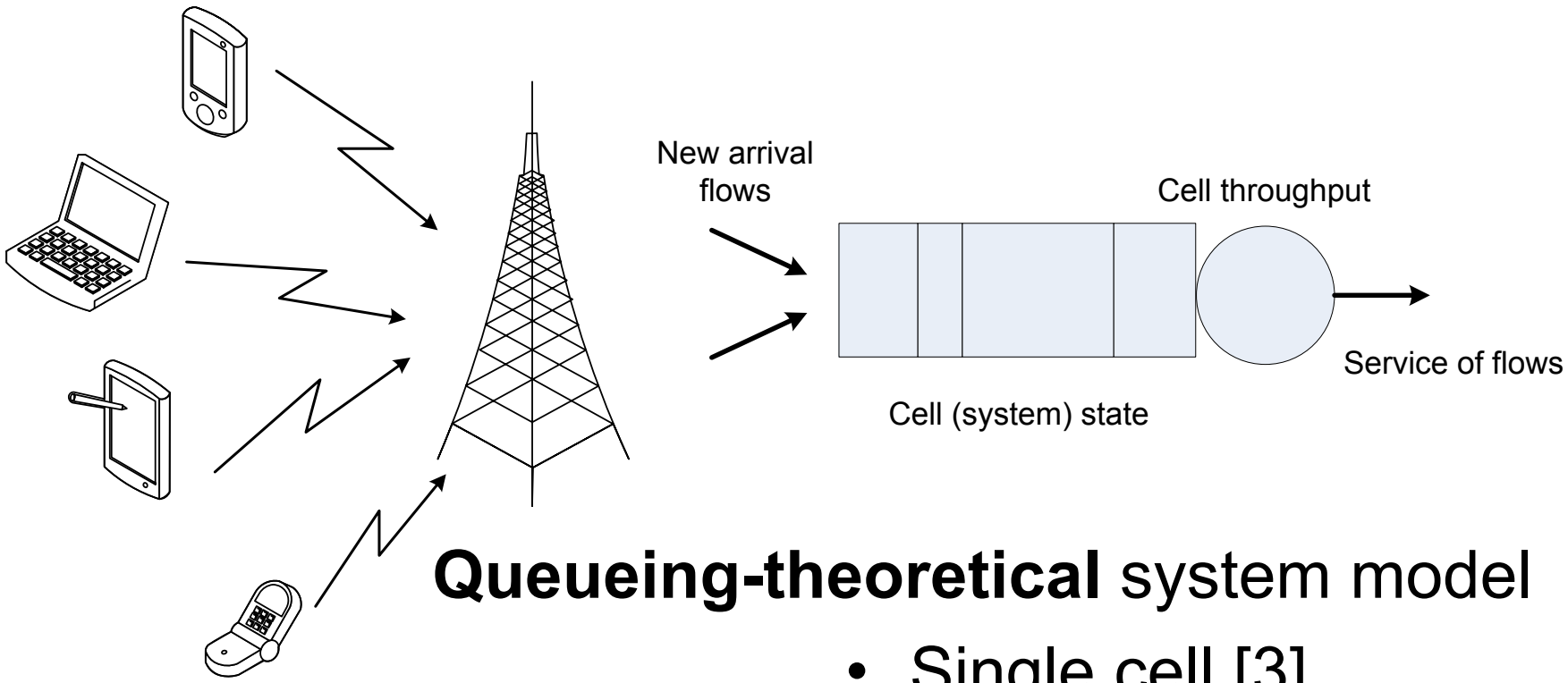
$$U_i(R) = \frac{R_i}{P_{c,i} + P_{tx,i}(R)} \quad (bits\ per\ Joule)$$

System metrics:

$$\frac{1}{N}\sum_{i=1}^{N} U_i(R) \qquad \left(\prod_{i=1}^{N} U_i(R)\right)^{1/N}$$

Inherent limitation: steady-state **saturation** conditions

Advanced Approach



Queueing-theoretical system model

- Single cell [3]
- Dynamic arrival flows
- Variable number of clients

Selected publications

1. S. Baek, J. J. Son, and B. D. Choi, “Performance analysis of sleep mode operation for IEEE 802.16m advanced WMAN,” MACOM, 2009.
2. G. Miao, N. Himayat, G. Li, and S. Talwar, “Low-complexity energy-efficient OFDMA,” IEEE ICC, 2009.
3. H. Kim and G. de Veciana, “Leveraging dynamic spare capacity in wireless systems to conserve mobile terminals’ energy,” IEEE/ACM Transactions on Networking, 2008.
4. J. Zhu, A. Waltho, X. Yang, and X. Guo, “Multi-radio coexistence: challenges and opportunities,” ICCCN, 2007.

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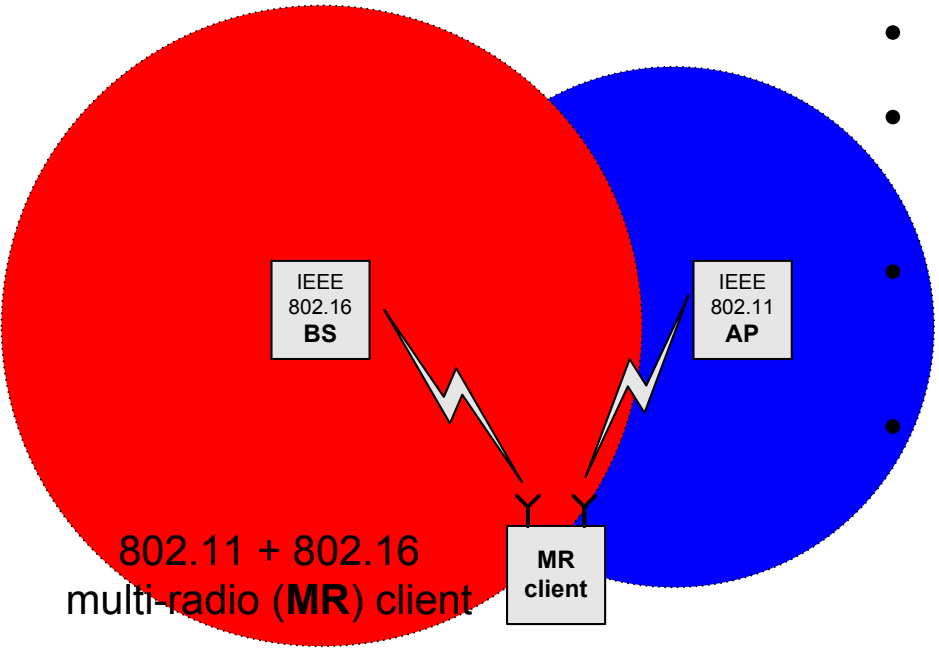
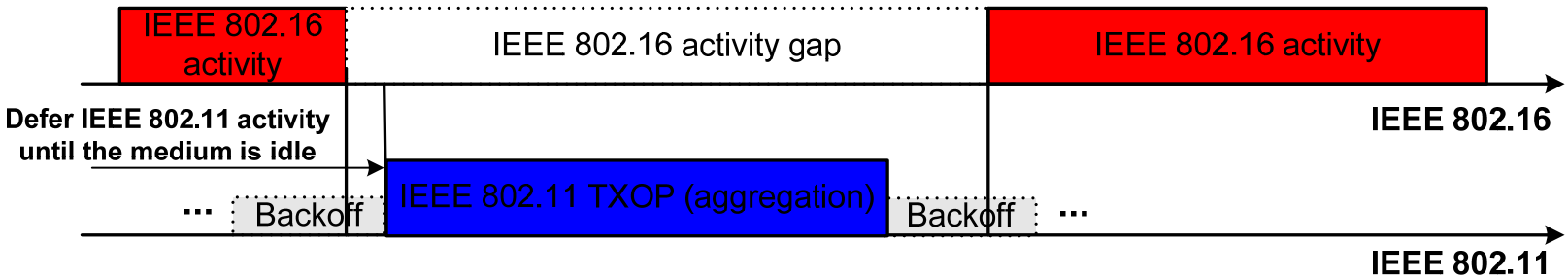
5. A. Anisimov, S. Andreev, and A. Turlikov, “IEEE 802.16m Energy-Efficient Sleep Mode Operation Analysis with Mean Delay Restriction,” ICUMT, 2009.
6. K. de Turck, S. Andreev, S. de Vuyst, D. Fiems, S. Wittevrongel, H. Bruneel, “Performance of the IEEE 802.16e sleep mode mechanism in the presence of bidirectional traffic,” GreenComm, 2009.
7. S. Andreev, K. Dubkov, A. Turlikov, “IEEE 802.11 and 802.16 cooperation within multi-radio stations,” in Wireless Personal Communications Journal (WIRE), accepted for publication, 2009.

Additional Research Targets

MAC Coordination Problem

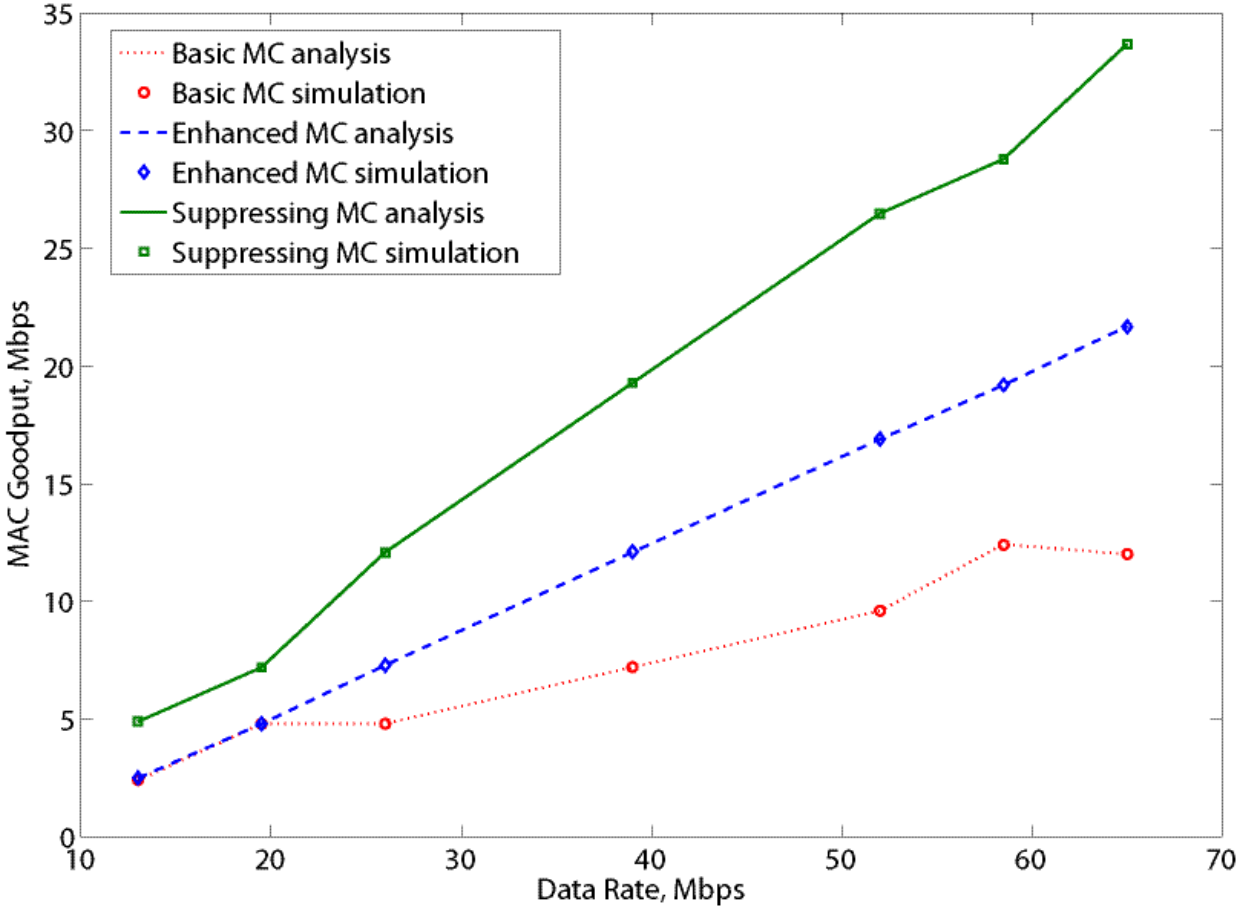


- IEEE 802.11 and 802.16 coexist
- Data packets corrupted due to MR interference
- Preventive measures are necessary → MAC coordination
- MAC coordinator defers 802.11 activity until 802.16 activity gap



See discussion in [7]

Achieved Gains



WiFi parameters

- Version: **IEEE 802.11n**
- TXOP size: **1.3 ms**
- CWmin/CWmax: **7/15**
- AIFS duration: **43 us**
- Slot time: **9 us**
- Packet length: **1500 bytes**

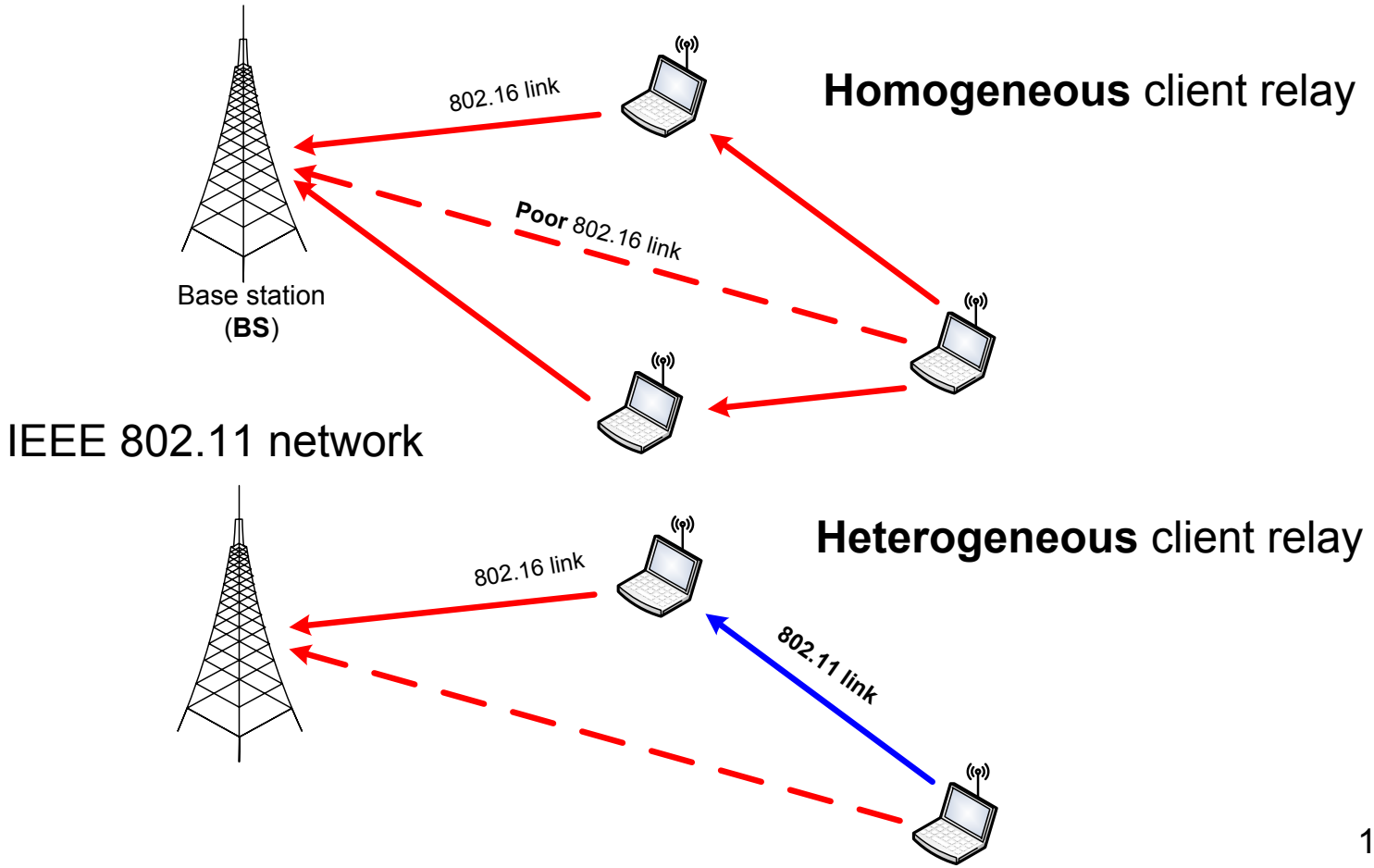
WiMAX parameters

- Version: **IEEE 802.16-2004**
- DL:UL ratio: **60:40**
- PHY type: **OFDMA**
- Frame duration: **5 ms**
- Rx-Tx gap duration: **2.5 ms**

Performance gain **> 50 %**

Client Relay Research

Goal: Enable client collaboration in 802.16



Plans and perspectives – I

- Research area is promising
  (low-power machine-to-machine communications)
- Only initial work is done
  + Preliminary performance evaluation
  + Hooks in IEEE 802.16m standard
  + GLOBECOM 2010 paper submitted
  + IDF prepared for submission
  – Static steady-state network environment
    (no traffic models for multimedia services)
  – Joint sleep/idle mode optimization
    is not accounted for

Plans and perspectives – II

- New system-level simulator to relax existing limitations
- Queueing-theoretical EE and CR models

International research team

Supervision

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