Guest Lecture :: IEEE WirelessMAN and Wide and Metropolitan Area Networks

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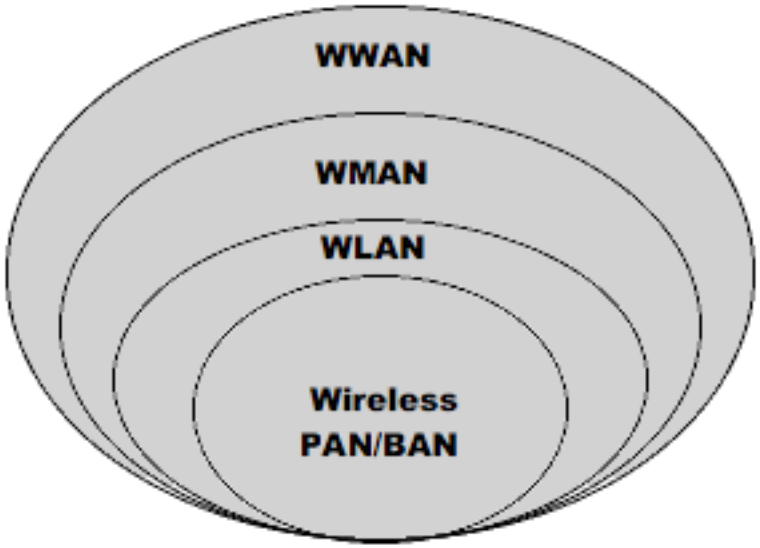
Today's Network Heterogeneity

- Wide Area Networks, WAN
  - Regional, national and international coverage
  - PSTN and Internet
  - Cable and Satellite TV
  - WWAN: GSM / GPRS / EDGE
  - WAN: SDH / SONET
- Metropolitan Area Networks
  - Covers the size of a city
  - MAN: ATM / Ethernet
  - WMAN: “Google WiFi“ Montain View, CA, 8
- Local Area Networks
  - “SoHo“ Small Office, Home Office, group of buildings
  - 802.3 (Ethernet) and 802.11 (wireless)
- Private Area Networks, PAN
  - Short-range communication, < room, Ethernet, Bluetooth, ZigBEE
- Heterogeneous networks
  - In services
  - In scale and technology

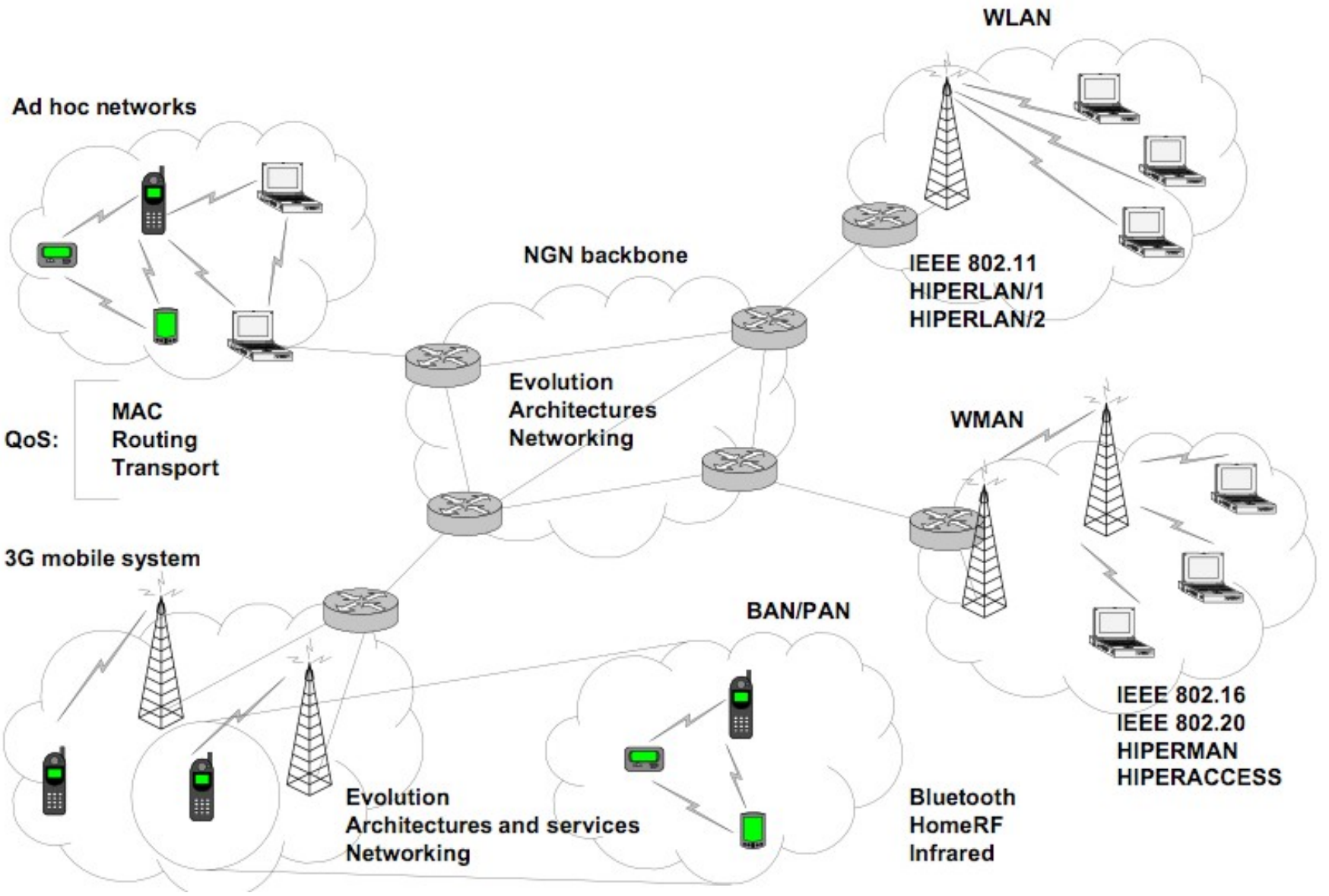


Next Generation Networking

- There are too many networks out there
  - PSTN – Primary for Voice and FAX
  - GSM – Primary for Voice
  - Cable TV – Broadcasting Television
  - Satelite Networks – TV but also Internet
  - ISDN – Multi-service network
  - and xDSL – Internet access

- But the past 15 years have thaught us
  - The Internet is the most flexible and powerfull network out of the whole set. Hence, why do we not use the Internet for all services?
- That's the principle idea of NGN
  - Unified Communications
    - One single infrastructure for all services
  - Convergence
    - Operation, Management is simplified and expenses are cut dramatically

NGN All-IP Architecture



Broadband Wireless Access

- But Many services call for powerful network access!
  - IPTV – A single session needs up to 3 Mbps and lasts ~ 2 hour
- And users expect services “Anytime, Anywhere“
- That's why we need Broadband Wireless Access
  - Why? It simply much cheaper and more flexible
    - Impervious and remote areas with little population
    - But also for highly dense populated areas. Who wants to crack the streets of Manhattan down town?
    - Supports mobility like users are used to from GSM/UMTS
- World Wide efforts in the area
  - IEEE 802.16 Working Group
    - “WirelessMAN Standard for Wireless Metropolitan Area Networks“
  - ETSI HIPERMAN
    - Took IEEE 802.16 standards as a baseline
      - mostly in terms of PHY layer
    - therefore, 802.16 and HIPERMAN
      - Shall comply with each other and consolidate into a global system
  - WiBro, South Korea

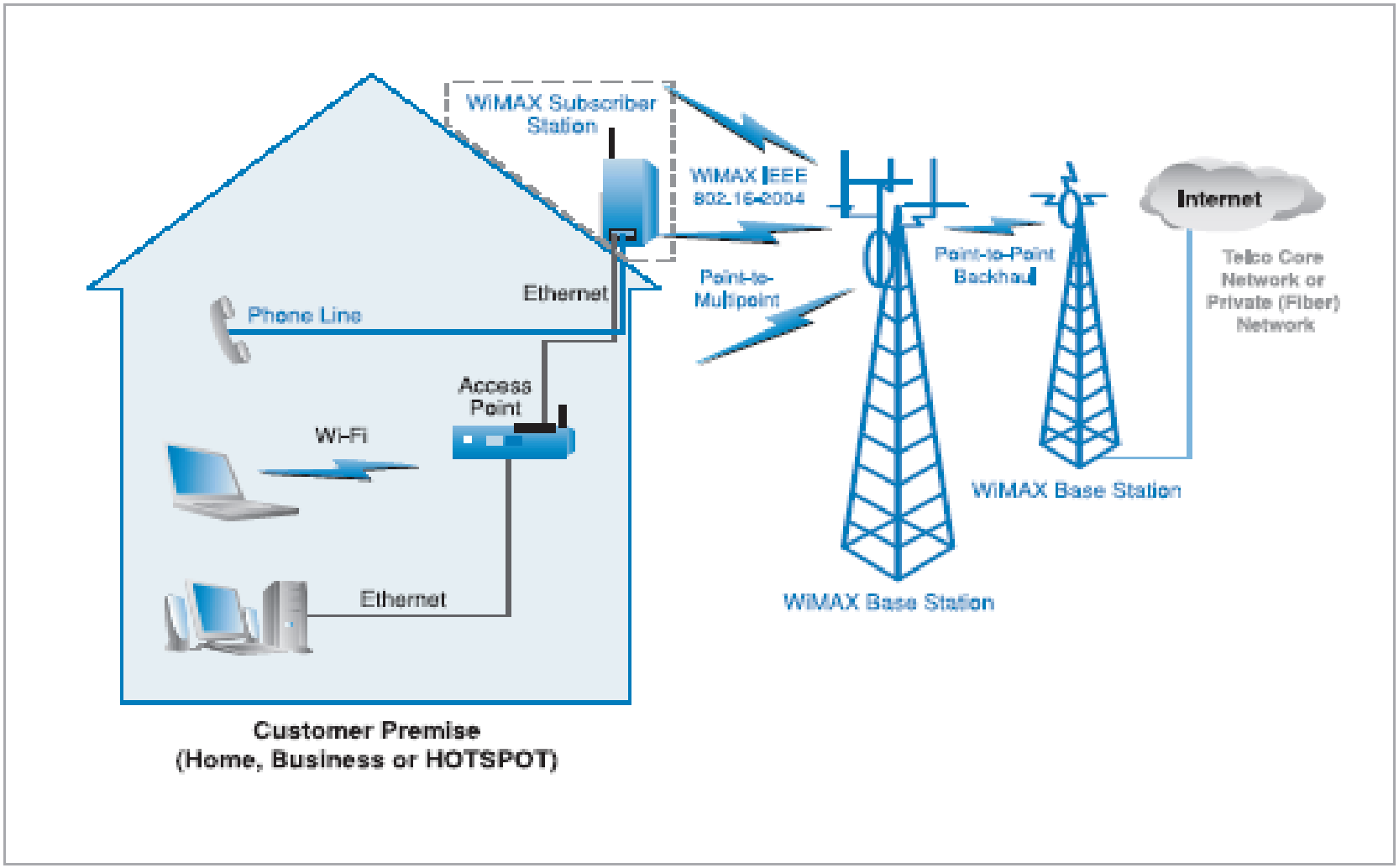
IEEE 802.16 WirelessMAN

- IEEE 802.16 WMAN Working Group
  - Founded in 1998 at the IEEE Radio and Wireless Conference, Colorado, USA
- Objective
  - Publishing a standard for Broadband Wireless Access
    - IP-oriented
    - Comprehensive QoS model
    - non-licensed bands and licensed band
    - long and short distance

IEEE 802.16 family

	802.16	802.16a	802.16REVd or 802.16-2004	802.16e
Approved	Dec. 2001	Jan. 2003	July 2004	App. July 2005
Spectrum	10 - 66 GHz	< 11 GHz	< 11 GHz	2 - 6 GHz
Propagation	LOS	NLOS	NLOS	NLOS
Modulation	QPSK, 16QAM и 64QAM	OFDM 256, OFDMA + 802.16	OFDM 256, OFDMA + 802.16	OFDM 256, OFDMA + 802.16
Speed	32 – 134 Mbps	1 – 75 Mbps	Like 802.16a	Up to 15 Mbps
Mobility	No	No	No	Yes, with roaming
Channel bandwidth	20, 25 and 28 MHz	Variable from 1,25 up to 20 MHz	Like 802.16a	> 5 MHz
Cell size	1 - 5 km	5 – 8 km, max. is 50 km with directional antenna	Like 802.16a	1 – 5 km
Terminal		External with external antenna	External with internal antenna	PC card

Component Overview – IEEE 802.16-2004

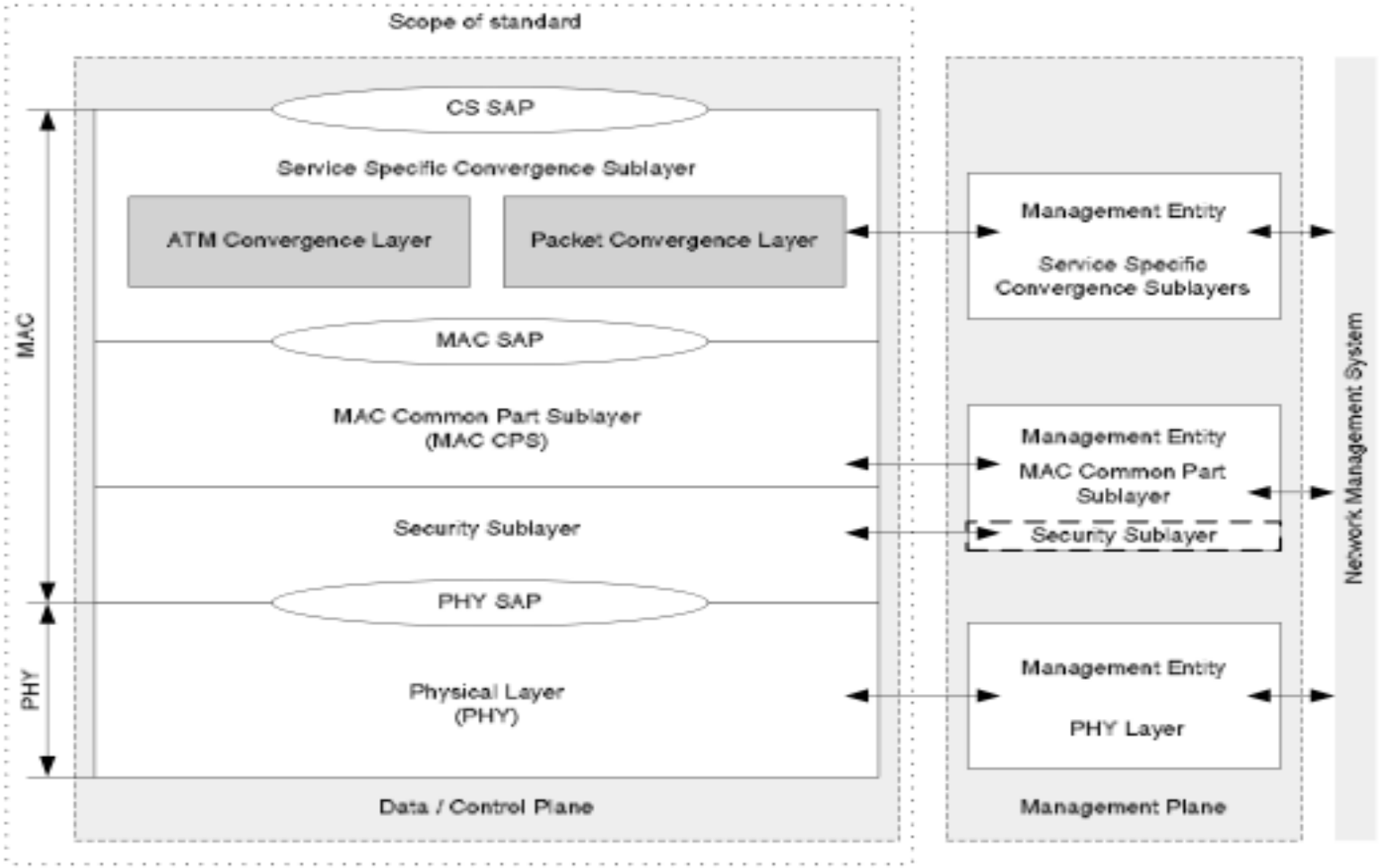


IEEE 802.16 Architecture

- IEEE 802.16 does define
  - Four different PHY and a generic MAC layer
- Key features are
  - Flexible and extensible common MAC
    - Independent from PHY
  - Modular
    - PHY and MAC are composed of different sub-layers
  - Different Network Topologies
    - Point-to-Point (PtP)
    - Point-to-Multipoint (PMP), Mesh
  - Duplexing
    - TDD and FDD support
  - Multiple Antenna Technologies
    - Omnidirectional, directional, sektorized
  - Subscriber-level adaptive PHY
    - per-connection channel aware communication
  - Convergence sub-layer
    - Ethernet and ATM convergence sub-layer

802.16 protocol stack

- IEEE 802.16 layers and sub-layers

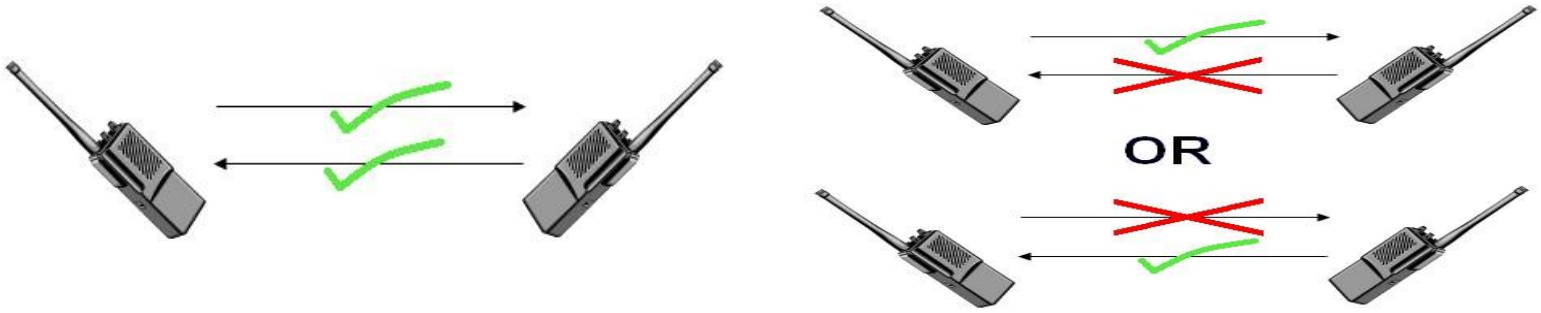


Base Station vs. Subscriber Station

- Base Station (BS) and Subscriber Station (SS) are in a Master-Slave relation
- Base Station
  - Enforces System configuration and parameter
    - Which PHY layer configuration (OFDM, OFDMA, SC, etc)
  - Coordinates Down-Link (DL) and Up-Link (UL) per-frame schedule
    - DL : BS->SS
    - UL : SS->BS
  - Bandwidth allocation for DL and UL per-frame/connection
  - Communicating per-frame schedule
- Subscriber Station
  - Establishes basic connectivity with a BS, called „Ranging“
  - Generates Bandwidth Requests
  - Makes local scheduling decisions
  - Transmits **only** when its is told to so

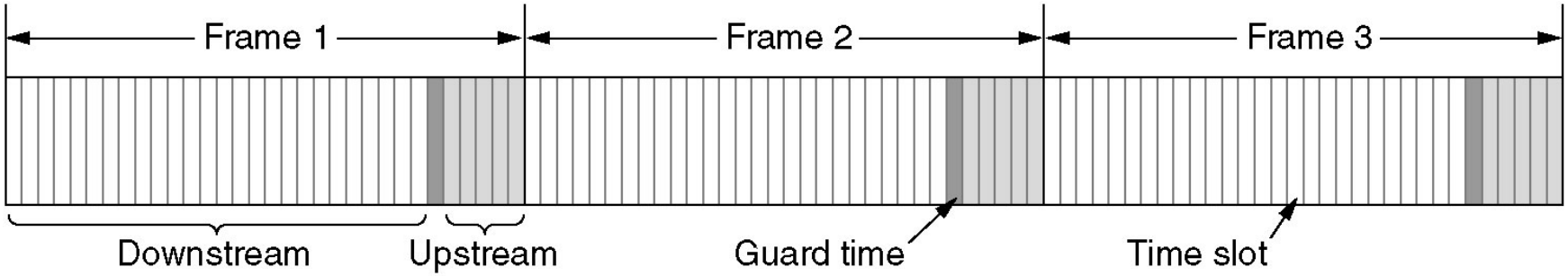
IEEE 802.16 Duplexing

- IEEE 802.16 supports full-duplex and half-duplex communication



- TDD is favourable since
  - It supports asymmetric and adaptive downlink/uplink ratios
  - TDD only requires a single channel
  - It allows greater flexibility for adaptation to global spectrum allocations
  - Its implementation is less complex, i.e. cheaper

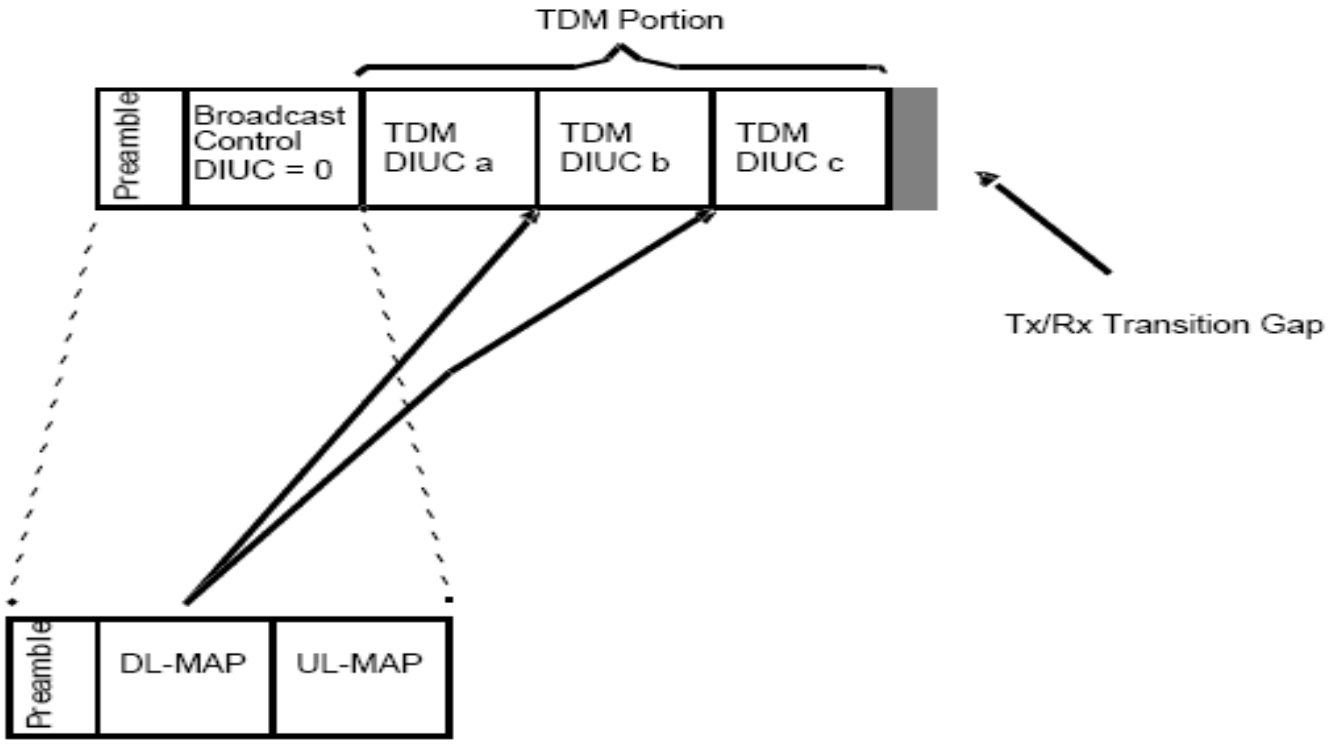
IEEE 802.16 TDD Framing



- TDD is favourable since
  - It supports asymmetric and adaptive downlink/uplink ratios
  - TDD only requires a single channel
  - it allows greater flexibility for adaptation to global spectrum allocations
  - its implementation is less complex, i.e. cheaper
- The BS is in charge of coordination of the resource, i.e. time slot assignment
- It has to communicate its decision to the Sss
- At the beginning of each frame there is a DL-MAP and a UL-MAP

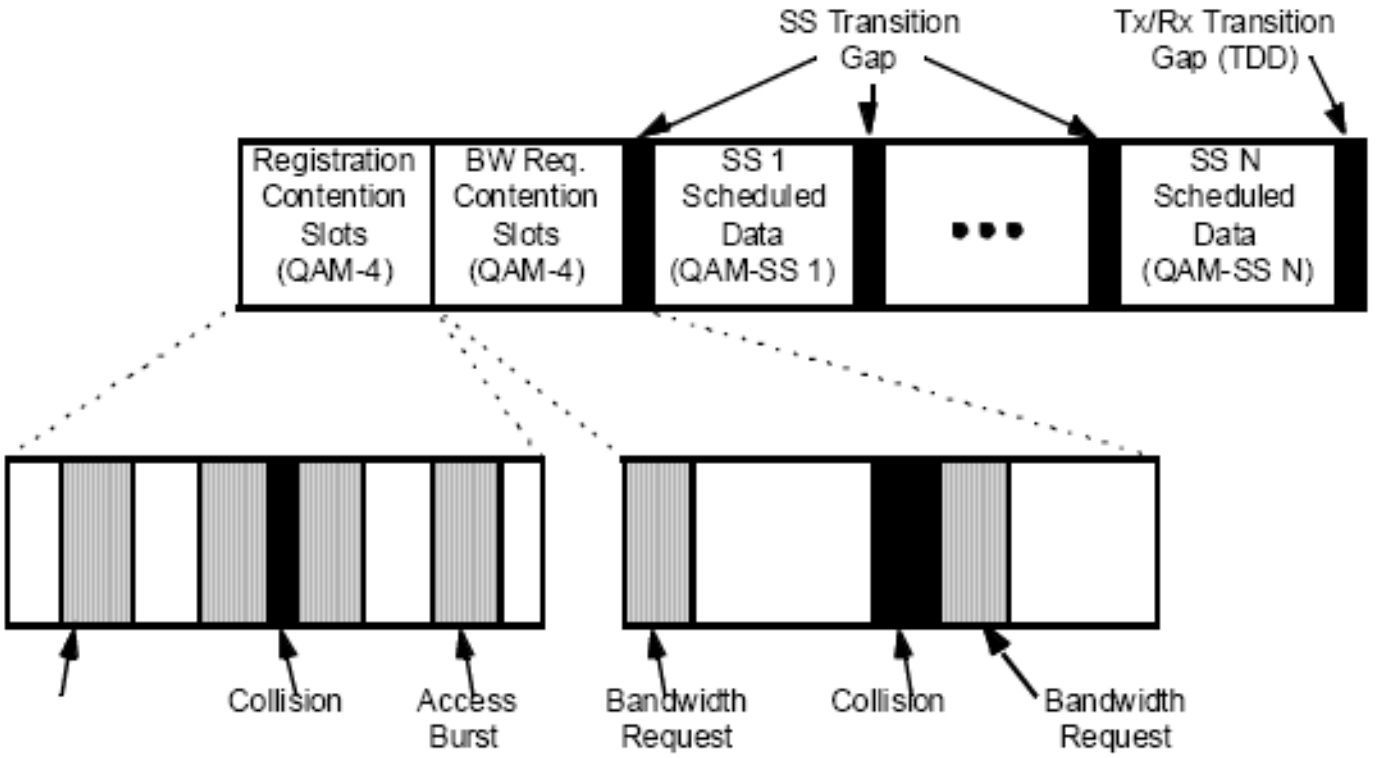
IEEE 802.16 TDD Framing

- TDD Down-link sub-frame
- In the DL-Map the BS broadcasts „what-is-when-for-whom“
- Hence, the BS broadcasts traffic (shared medium!) and all SSs listen
- Therefore collision free communication



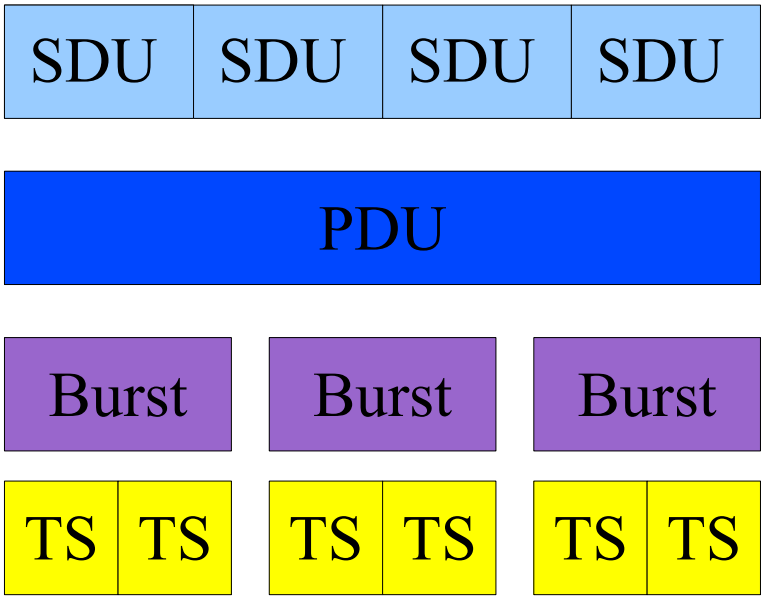
IEEE 802.16 TDD Framing

- TDD Up-Link sub-frame
- In the UL-Map the BS communicates “who-sends-when-how-long“

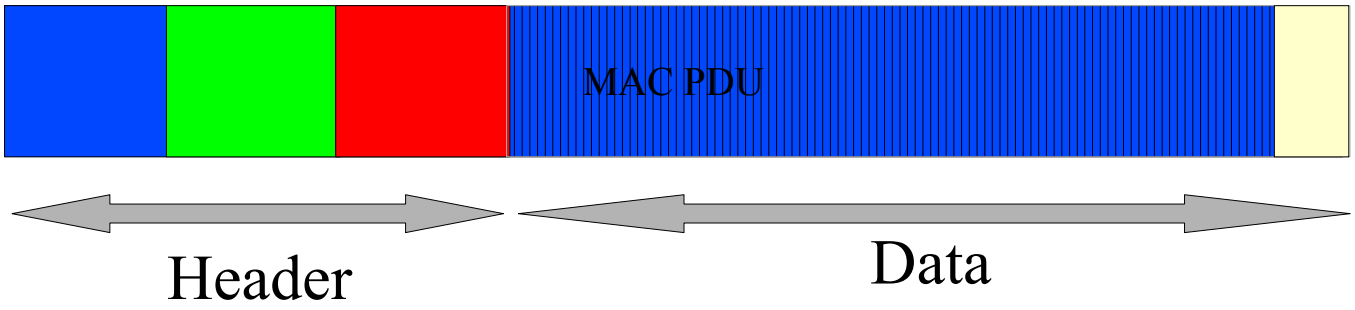


From Packets to Time Slots

- Service Data Unit (SDU) is an entity from upper level (e.g. IP packets)
- SDU(s) are encapsulated in a MAC Protocol Data Unit (PDU)
- MAC PDU are transmitted within so-called data bursts
- A data burst is made of one or multiple time slots
- There are rules on how SDUs are splittedtween PDUs
- No restrictions on how many PDUs are put into bursts
- However, the maximum PDU size is 4096 Bytes
- The final restriction for data burst size is the frame size

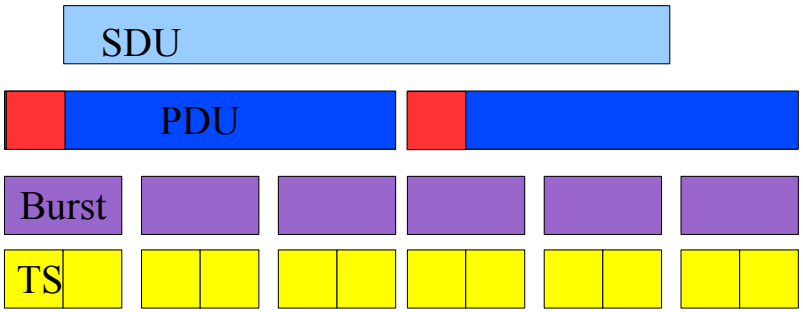


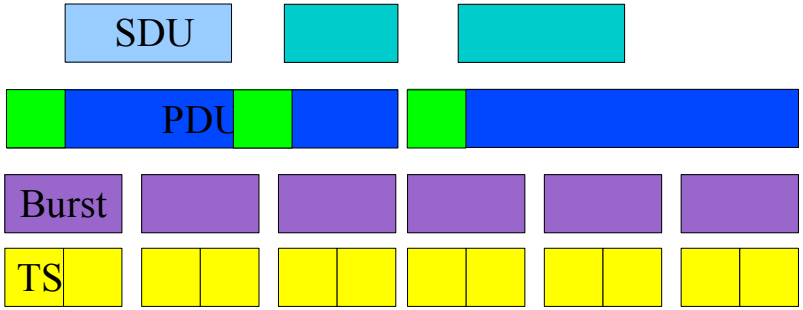
IEEE 802.16 MAC Protocol Data Unit



- MAC Protocol Data Unit
  - Basic transmission unit
  - One header and optional subheaders
    - Fragmentation subheader
    - Packing subheader
    - Grant management subheader
  - MAC PDU possibly entails a CRC field

Fragmentation and Packing





- Fragmentation
  - SDU exceeds the maxium size (4096B) of the PDU
  - SDU is split over multiple PDUs
  - to identify fragments, each PDU has a fragmentation subheader (FS)
- Packing
  - Multiple SDUs are packed into one PDU
  - For each each SDU, the packing subheader (PS) is required
  - Packing also supports SDU fragments SDU

IEEE 802.16 Connection Orientation

- IEEE 802.16 is connection oriented
  - Species a unidirectional logical connection at the link-level
  - Link-level means between two peered MAC instances
  - Multiple connections can exist per one SS/BS pair
  - Always explicitly established and have a unique identifier (CID)
  - Encodes source, destination, and the service access point
- Connection types
  - Initial
    - Used by an SS while entering the network
  - Basic
    - BS created at network entry
    - Used by an SS to send priority MAC signalling messages
  - Management (primary and secondary)
    - BS created at network entry
    - Used by an SS to for signalling related to MAC but also by higher level protocols
  - Transport
    - Initiated by an SS (optional feature) or BS (mandatory feature)
    - Used to user data
    - Has QoS parameters assigned

IEEE 802.16 Access Management

- CSMA/CD (IEEE 802.3 Ethernet)
  - Stations sense the carrier
  - No access priority for individual stations
  - Collision detection and resolution, backoff for a random period and try again
- CSMA/CA (IEEE 802.11 WLAN)
  - Stations sense the carrier
  - No access priority for individual stations
  - Stations try to avoid consecutive collisions by using a backoff mechanism
- DAMA (IEEE 802.16 WiMAX)
  - Demand assigned multiple access
  - Stations listen for UL data, and stay idle until they do not have data to send
  - If they have data, they request UL bandwidth (times slots in TDD)
  - A station can send data only when the BS allocates resources

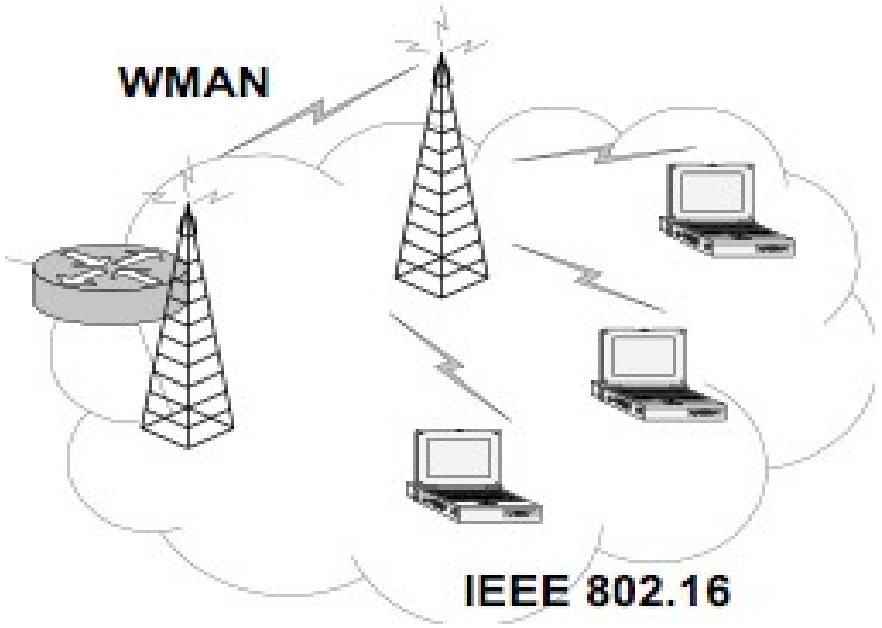
IEEE 802.16 Resource Management

- Depending on the number of the connections, two allocation modes are available:
- Per Connection Grant
  - SS can maintain several transport connections
  - Each has its own QoS requirements
  - The BS allocates resources for each connection
  - Unfavourable due to poor scalability
    - BS has to keep states for a large number of transport connections
  - Example:
    - One VoIP/G.711 connection needs max. 64KBps
    - 23.52 MBps / 64 Kbps = 367 Connections
    - Recall capacity can be up to 130MBps -> ~ 2200

Mod.	Code Rate	5 MHz Channel		10 MHz Channel	
		Downlink Rate, Mbps	Uplink Rate, Mbps	Downlink Rate, Mbps	Uplink Rate, Mbps
QPSK	1/2 CTC, 6x	0.53	0.38	1.06	0.78
	1/2 CTC, 4x	0.79	0.57	1.58	1.18
	1/2 CTC, 2x	1.58	1.14	3.17	2.35
	1/2 CTC, 1x	3.17	2.28	6.34	4.70
	3/4 CTC	4.75	3.43	9.50	7.06
16QAM	1/2 CTC	6.34	4.57	12.67	9.41
	3/4 CTC	9.50	6.85	19.01	14.11
64QAM	1/2 CTC	9.50	6.85	19.01	14.11
	2/3 CTC	12.67	9.14	25.34	18.82
	3/4 CTC	14.26	10.28	28.51	21.17
	5/6 CTC	15.84	11.42	31.68	23.52

IEEE 802.16 Resource Management

- Per Subscriber Station Grant
  - Only one transport connection per SS
  - SS requests bandwidth for the traffic aggregate
  - BS allocates resources for the aggregate
  - The SS assigns resources to individual flows by local scheduling
  - Complexity is distributed and hence the burden shared



IEEE 802.16 Resource Management

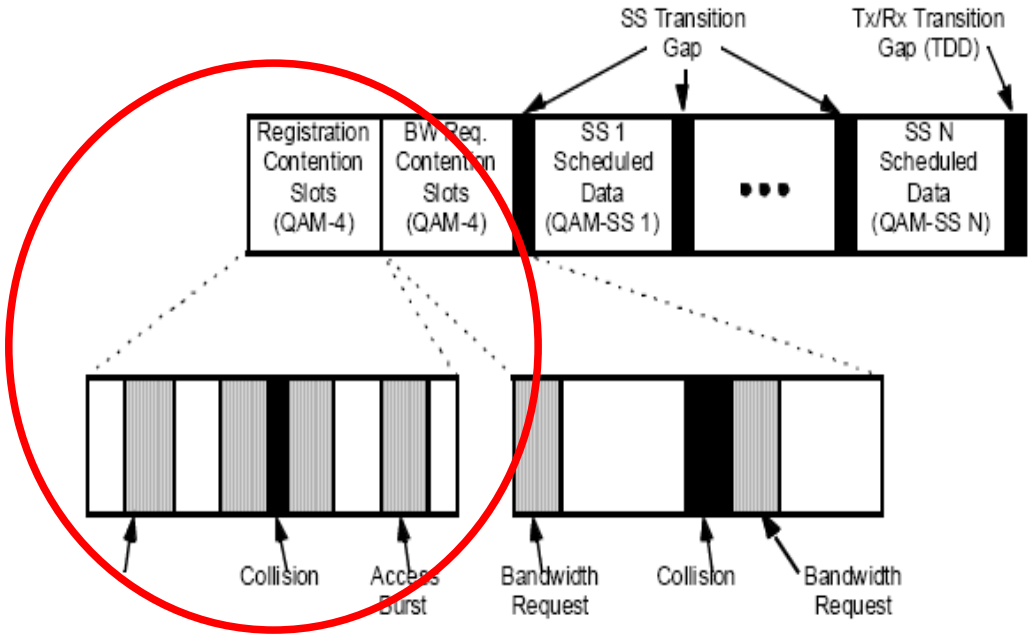
- The SS has to inform the BS about required UL resources
- The BS decides how to achieve QoS aware but fair resource allocation
- Types of Bandwidth Request
  - Aggregated
    - The size of the complete output buffer is sent to the BS
  - Incremental
    - delta previous bandwidth request size and current buffer size is sent
- But how can an SS send bandwidth requests?
  - Piggy-back message
    - Only when it has already data and bandwidth
    - Only incremental requests
  - Standalone message
    - Separate MAC PDU
    - Either incremental or aggregated requests

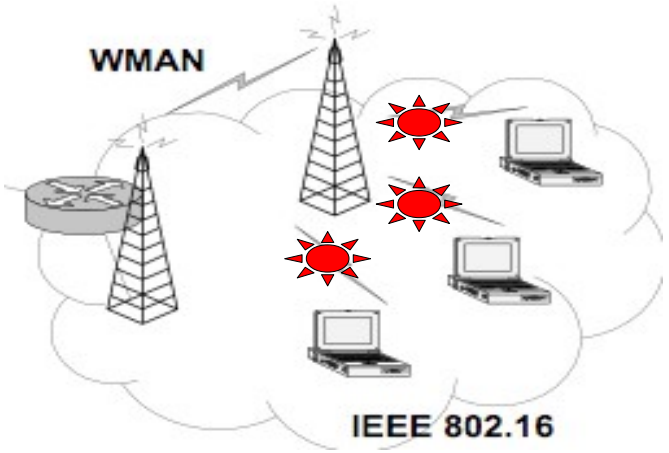
IEEE 802.16 Resource Management

- To send standalone message, an SS already needs bandwidth
  - Henn-egg problem!
- So how to get bandwidth to send bandwidth requests?
- IEEE defines two methods
  - Polling
  - Contention based
- Polling
  - A BS allocates in regular intervalls small units of BW for a SS
  - Allocation unit is only for an individual SS
  - SS uses this BW to send a BW request if it has to send data
  - Polling interval depends on the service type:
    - Few milliseconds for time-critical services
    - Up to some seconds for non-critical services
  - No BW request conflicts, e.g. collisions
- Again, this can incurr scalability issues
  - A huge number of time-critical connections can consume signicant amount of resourcess

IEEE 802.16 Resource Management

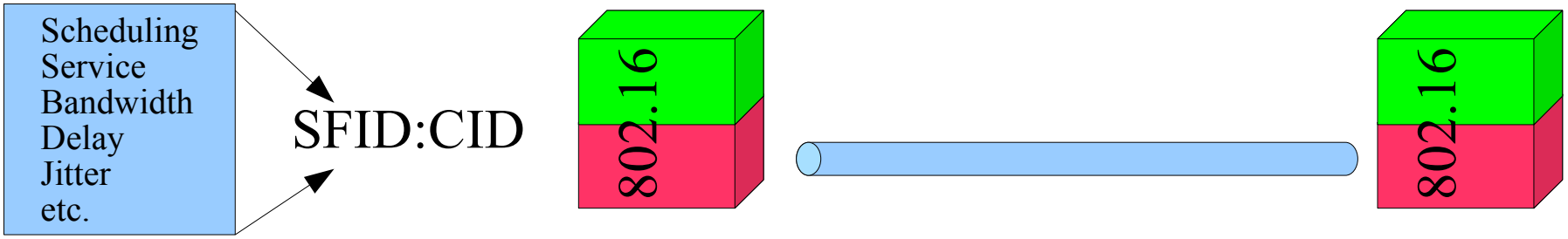
- Contention based BW requesting
  - BS allocates request contention slots
  - Each SSs can send the bandwidth requests during this period
  - Simulultaneous requests cause collisions
  - Hence, can not be used for the time-criticsl applications
  - Predominantly meant for the BE services





IEEE 802.16 Service Flows

- The IEEE QoS model supports a set of different services
- Services to support applications like
  - RT: VoIP, IPTV, VoD
  - BE: FTP, HTTP
- For this reason, IEEE 802.16 introduces the concept of Service Flows
- Each service flow has an unique ID (SFID) and identifies a specific service
- Each connection (CID) is associated with one SFID
- CID for “peer addressing”, SFID for “service addressing“
- But not all connections are associated with a SFID
  - Recall the management connections
- Each connections is associated with a service, which again is associated with a set of specific QoS parameters



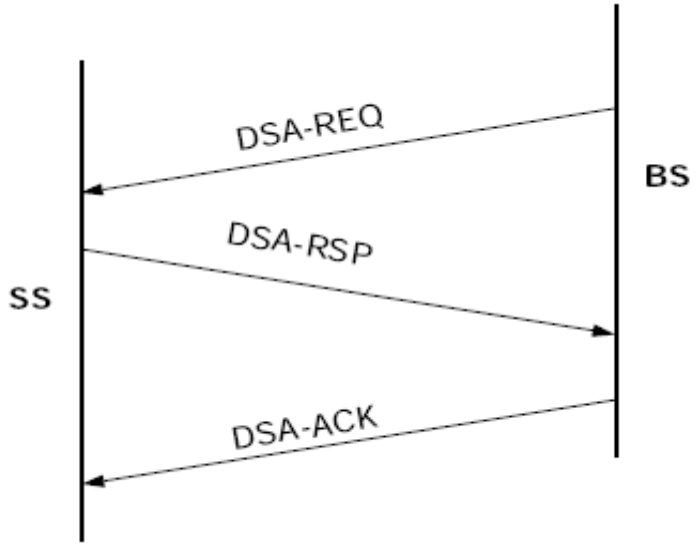
IEEE 802.16 UL Services Classes

- Unsolicited Grant Service (UGS)
  - Constant rate applications, e.g. VoIP without VAD
  - A connection is assigned periodically BW allocated
  - QoS: maximum rate, tolerated jitter, maximum latency
- Extended real-time Polling Service (ertPS) 802.16e
  - VoIP with VAD,
  - When active periodic BW allocation, if inactive being polled
  - QoS: maximum/minimum trafc rate, maximum latency
- Real-time Polling Service (rtPS)
  - Variable rate applications, e.g. IPTV data
  - Applications have to request for BW, piggy-back, polling
  - QoS: maximum trafc rate, tolerated jitter, maximum latency
- Non-real-time Polling Service (nrtPS)
  - Critical applications without strict timing requirements
  - Applications have to request for BW, contention, piggy-back, polling
  - QoS: maximum/minimum trafc rate, trafc priority
- Best Effor (BE)
  - Non-critical applications
  - QoS: maximum trafc rate, trafc priority

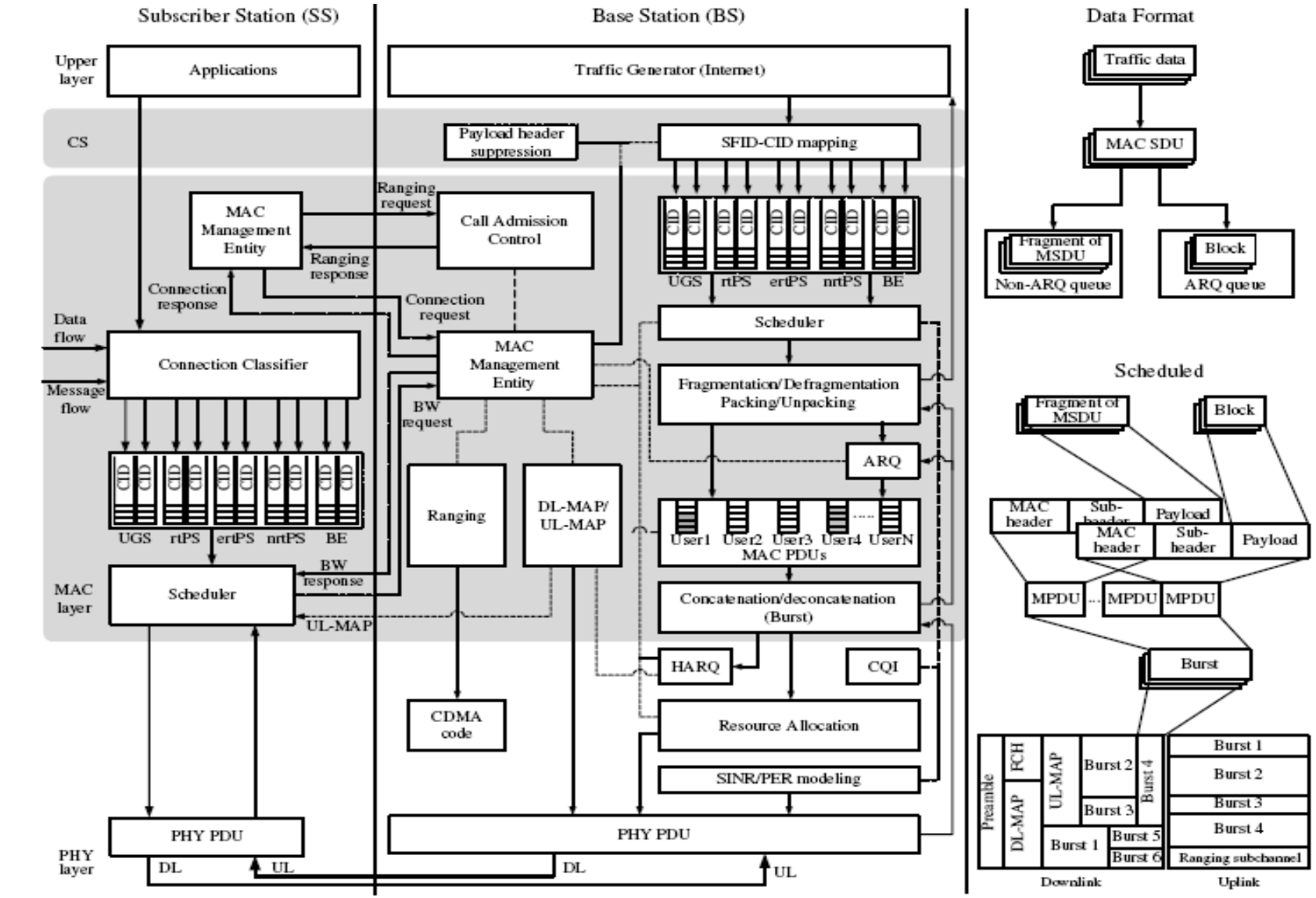
IEEE 802.16 Service Flow Management

- Service flows can be
  - Preprovisoned
    - During network entry the BS creates a pre-configured service flow
  - Created on demand
    - BS (mandatory feature) can create a new service flow
    - SS (optional featue) can request the creation of a new service flow
  - Active or inactive
    - A service flow which is currently not used to transmit data can be set idle
    - Think about traffic during the night
    - It can be reactivated on request

- Dynamic Service Addition (DSA)
  - BS intitated
  - Could be SS intitated
- Dynamic Service Change (DSC)
  - Change QoS parameters
- Dynamis Service Deletion (DSD)



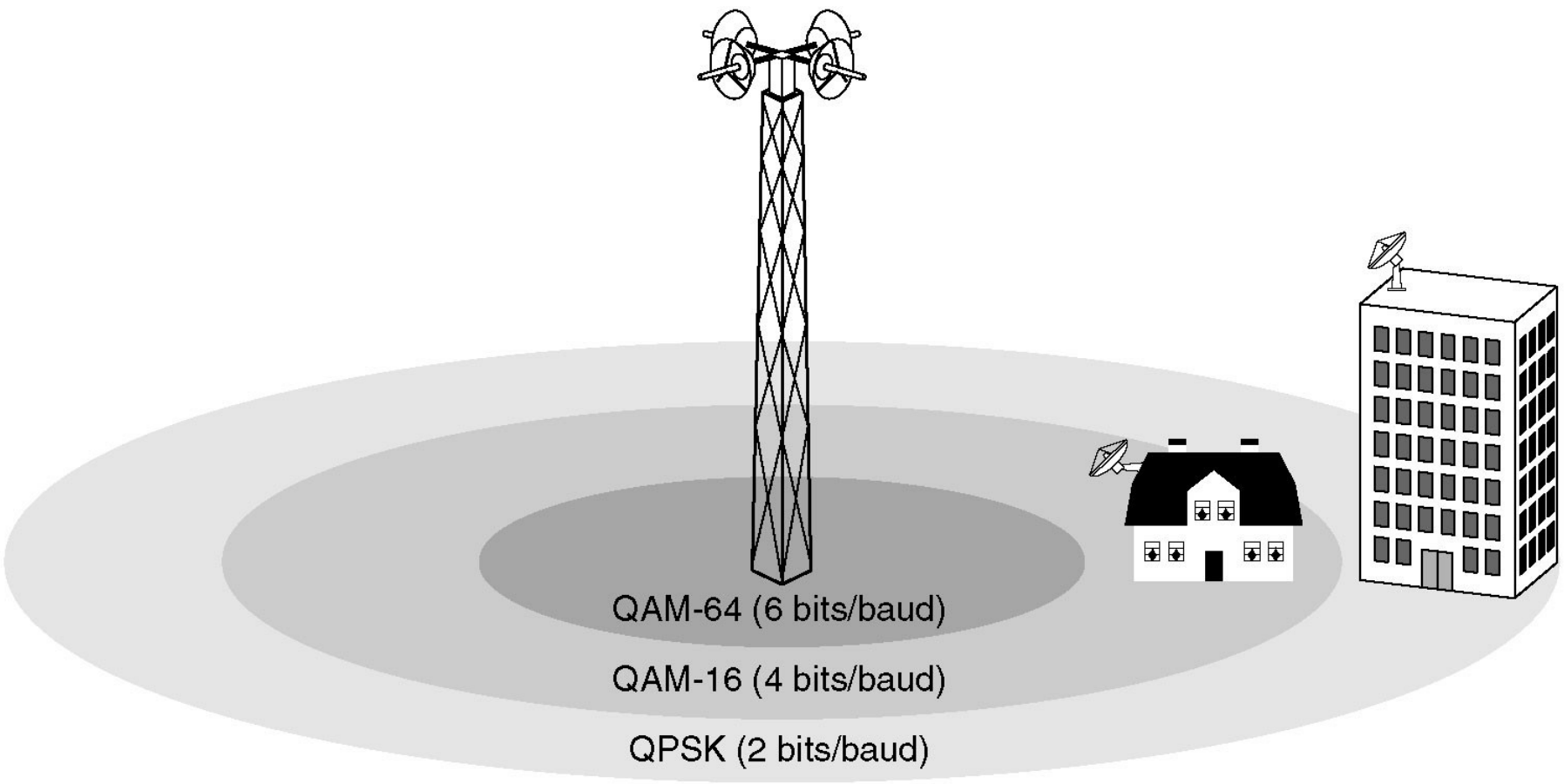
IEEE 802.16: A Complete Picture



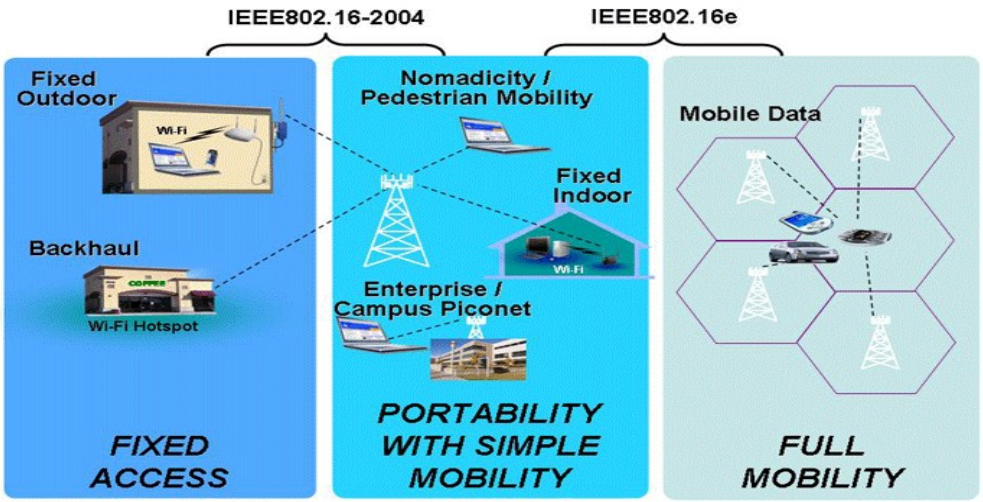
IEEE 802.16 Physical Layer in Brief

- 10–66 Ghz Spectrum
  - Deemed to require Line-Of-Sight (LOS) propagation
  - Hence, single-carrier modulation
  - called “WirelessMAN-SC“
- 2-11 Ghz Spectrum
  - Non-Line-Of-Sight (NLOS)
  - For residencial areas where rooftops are low and obstacles everywhere
  - Has to deal with extensive Mulitpath propagation
  - Defined are
    - “WirelessMAN-SCa“
    - “WirelessMAN-OFDM“
    - “WirelessMAN-OFDMa“
    - “WirelessHUMAN“
- Advanced features
  - Adaptive modulation and coding (AMC)
  - Fast Channel Feedback (CQICH)
  - Smart Antenna Technologies
    - Beamforming:
      - Multiple-antennas transmit weighted signals to improve coverage/ capacity
  - etc.

IEEE 802.16 Efficiency



IEEE 802.16e



- Mobility Extension Key Features
  - Per sector in a 10 MHz channel
    - Peak DL data rates up to 63 Mbps
    - Peak UL data rates up to 28 Mbps
  - Robust link adaptation in mobile environments at vehicular speeds in excess of 120 km/hr.
  - Hndover schemes with latencies less than 50 millisecond

IEEE 802.16e – Mobility Management

- Power Management
  - Sleep Mode
    - In this state the MS conducts pre-negotiated periods of absence
    - Minimal MS power BS air interface resources
  - Idle Mode
    - A mechanism for the MS to become periodically available for DL broadcast traffic messaging without registration at a specific base station
    - Ideal if the MS traverses an environment with multiple base stations
    - No handover required
- Handoff (HO)
  - Hard Handoff (HHO)
    - Break-before-make
  - Fast Base Station Switching (FBSS)
    - MS and BS maintain a list of „Active BSs“
    - MS is attached to an Anchor BS (ABS)
    - MS monitors signal strentgh
      - If below thres, select better BS for becoming ABS
      - During HO data is mulitcasted to ALL „Active BSs“
  - Macro Diversity Handover (MDHO)

WiMAX Forum

- Worldwide Interoperability for Microwave Access (WiMAX)
  - WiMAX is NOT 802.16!
- Founded in April 2001
- Non Profit organization that supports and promotes WiMAX's commercial usage
- Members include Intel, AT&T, Siemens Mobile, British Telecommunications, France Telecom, Qwest, …, yes, and NOKIA
  - Carl Eklund from Nokia Research was one of the early pioneers
- Main Objectives
  - “WiMAX Forum Certified Product“
    - Ensure product interoperability

WiMAX - Certification

- WiMAX Forum Certified Product
  - Ensure product conformance and interoperability

- WiMAX Forum Certified™
  - Radio conformance and interoperability
  - 802.16-2004 and 802.16e-2005

An Example:

CERTIFICATION CERTIFICATE

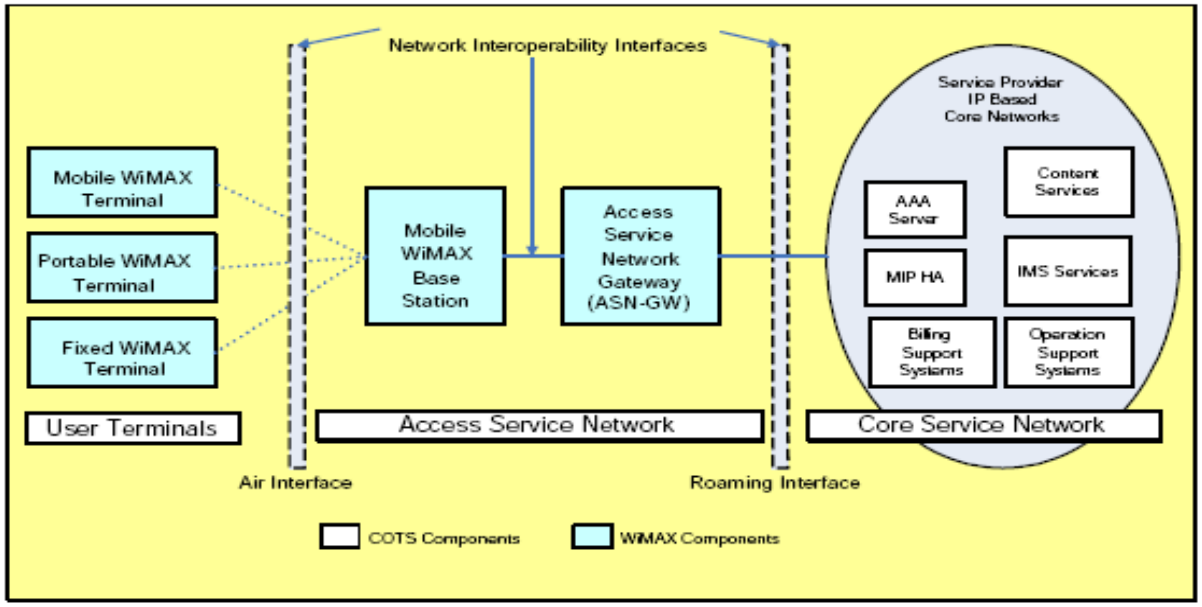
WiMAX FORUM

COMPANY NAME	Aperto
CERTIFICATION DATE	January 17, 2006
Air 1	
PRODUCT NAME	PacketMAX 5000
PRODUCT MODEL	PM5000
DEVICE TYPE	Base Station
CERTIFICATION NUMBER	01-0000000001
CERTIFICATION WAVE RELEASE	1.0
PROFILE	3.5GHz 3.5MHz TDD
HARDWARE VERSION	PM5000 WSC-S-24 Rev3, PM5000 MSC Rev7, PacketMax 3.5GHZ Radio Rev1
SOFTWARE VERSION	Build36 2005-12-09
TESTED BY	CETECOM Laboratories, Malaga, Spain

- Mobile WiMAX Certification Profiles based on frequency bands and channel bandwidths
  - 2.3-2.4, 2.5-2.7 or 3.3-3.8 GHz
  - 5, 7, 8.75 or 10 MHz channel bandwidths

WiMAX – All-IP NGN

- WiMAX is reaching far beyond 802.16
  - Defines a complete All IP End-to-End Network (Reference Model)
  - “Inter-vendor, inter-network interoperability for roaming, multi-vendor access networks, and inter-company billing“
  - Interfaces and protocols are based on IETF (open) standards
  - One main objective is 3GPP(2) interoperability



IEEE WirelessMAN / WiMAX Research

- European Research Projects
  - European Information Society Technology (IST) FP6 Integrated Project: "WiMAX Extensions to Isolated Research Data Networks (WEIRD)"
    - www.ist-weird.org
  - European Science Foundation COST 290 Action: "Wi-QoST::Traffic and QoS Management in Wireless Multimedia Networks" LINK
    - www.cost290.org
    - Chaired by Yevgeni Koucheryavy, here at TUT
- There are a plethora of research subjects
  - Scheduling
  - Admission Control
  - Performance Analysis for RT
  - etc. etc.
- Interested? You want to know more or get involved?
  - Feel free to contact me. thomas.bohnert@tut.fi
  - For some more info and a copy of this slides visit
    - wimax.nginet.de

Thank you

- Hopefully there is still time now for your questions ... Feel free!

- P.S. „Eleven reasons for studying in Coimra, Portugal“