

Mesh Networks in IEEE project 802

Guido R. Hiertz

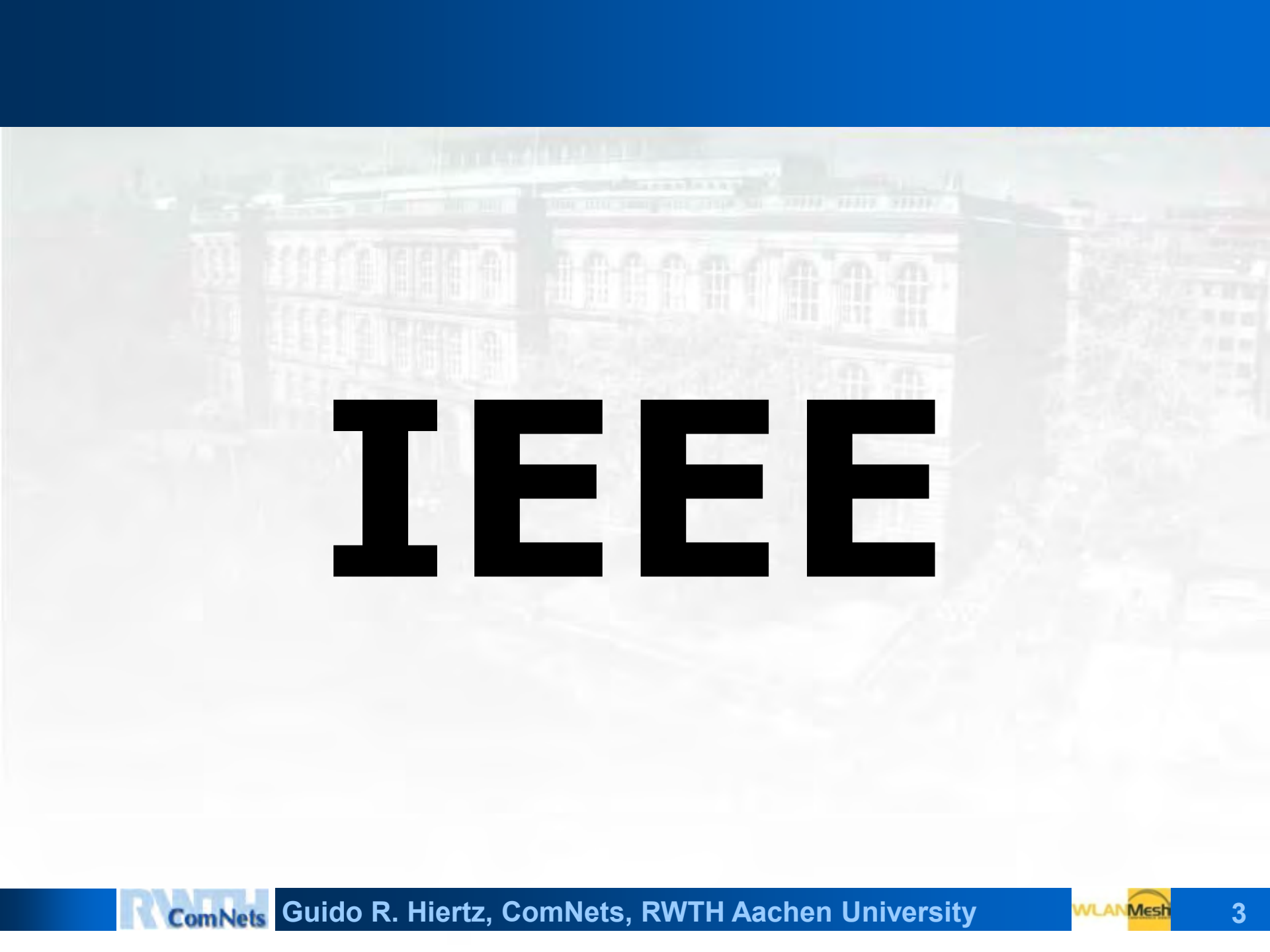
Chair of Communication Networks
RWTH Aachen University, Germany

2007-04-20, Paris, France

Overview

Overview – IEEE – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- IEEE
 - Introduction to standardization
- IEEE 802.15.5
 - WPAN Mesh
 - WiMedia
- IEEE 802.11s
 - WLAN Mesh
 - Wi-Fi Alliance
- IEEE 802.16j
 - Mobile Multihop Relay
 - WiMax Forum
- Summary



IEEE

The Institute of Electrical and Electronics Engineers (IEEE)

Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

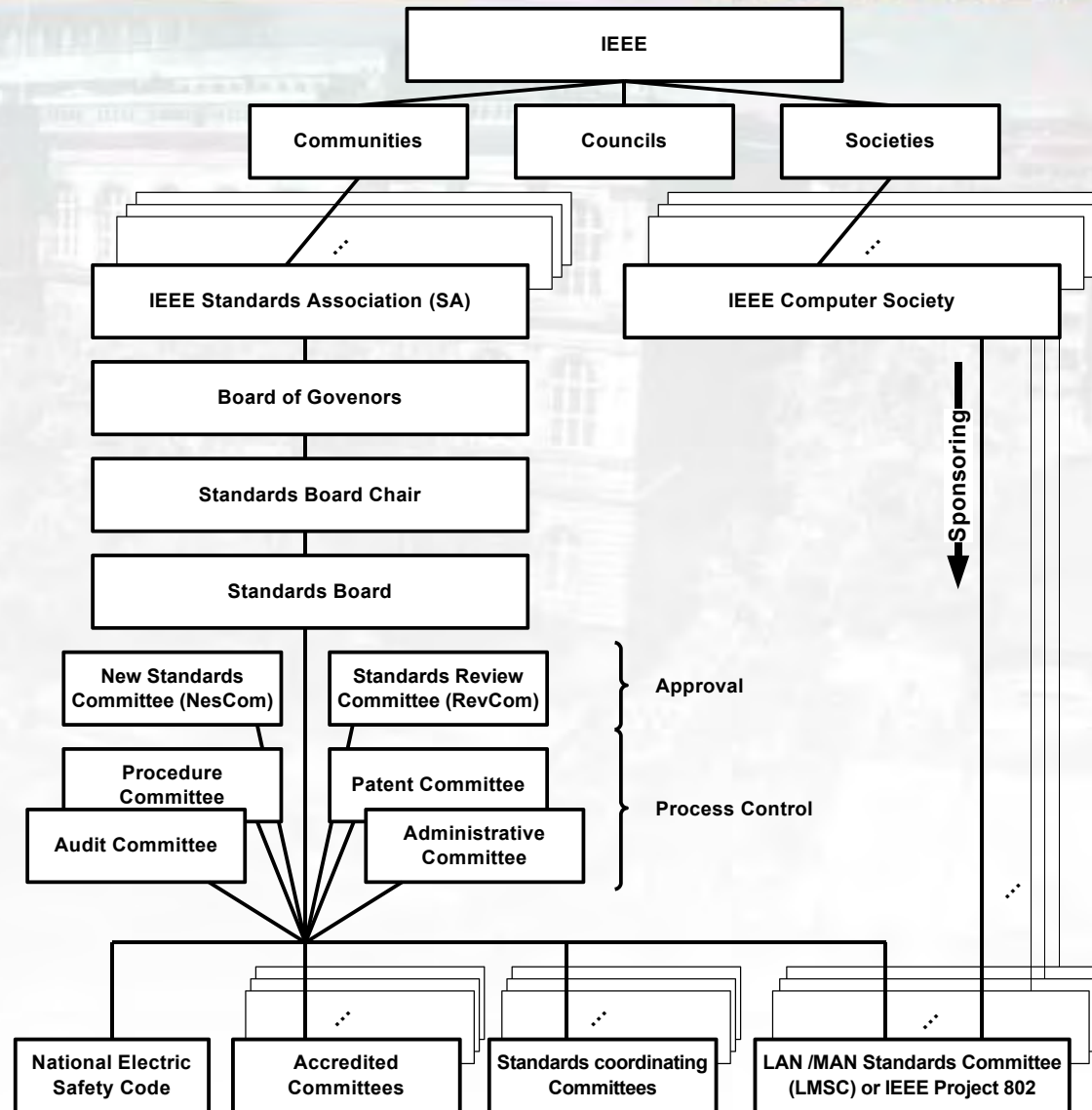
- Non-profit organization
- >370,000 members
- >150 countries
- Merge in 1963
 - American Institute of Electrical Engineers (AIEE)
 - Institute of Radio Engineers (IRE)
- Standards Association (SA)
- Leading authority
 - Aerospace
 - Computers
 - Telecommunication
 - Biomedical engineering
 - Electric power
 - Consumer electronics

Developing standards in the IEEE

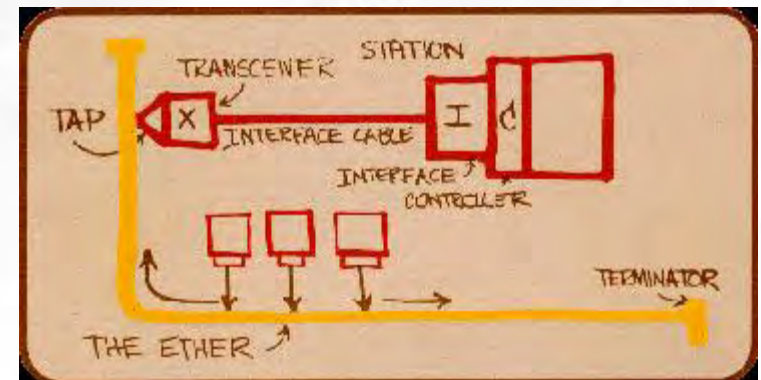
Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary



- New projects to be approved by NesCom
 - 4 meetings/year
 - Approximately 90 days



- First meeting in February 1980
 - LAN standard
 - Ethernet
 - Physical (PHY)
 - Media Access Control (MAC)
 - Higher Level Interface (HILI)
- Tremendous growth
 - Already in 1981
 - CSMA/CD
 - Token Bus
 - Token Ring
- IEEE Project 802



IEEE 802 – Today

Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- Mainly lowest 2 layers of OSI reference model
- Individual Working Groups (WG)
- Plenary sessions in March, July & November
- Body Area Network (BAN)
- Personal Area Network (PAN)
- Local Area Network (LAN)
- Metropolitan Area Network (MAN)
- Regional Area Network (RAN)



802 – Disbanded Working Groups

Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- 802.6
 - Metropolitan Area Network
- 802.7
 - Broadband TAG
- 802.8
 - Fiber Optic TAG
- 802.14
 - Cable Modem Working Group (Temporarily housed off-site)
- QOS/FC
 - Executive Committee Study Group

802 – Inactive Working Groups (hibernating)

Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- 802.2
 - Logical Link Control
- 802.4
 - Token Bus
- 802.5
 - Token Ring
- 802.9
 - Isochronous LAN
- 802.10
 - Security
- 802.12
 - Demand Priority

802 – Active Working Groups

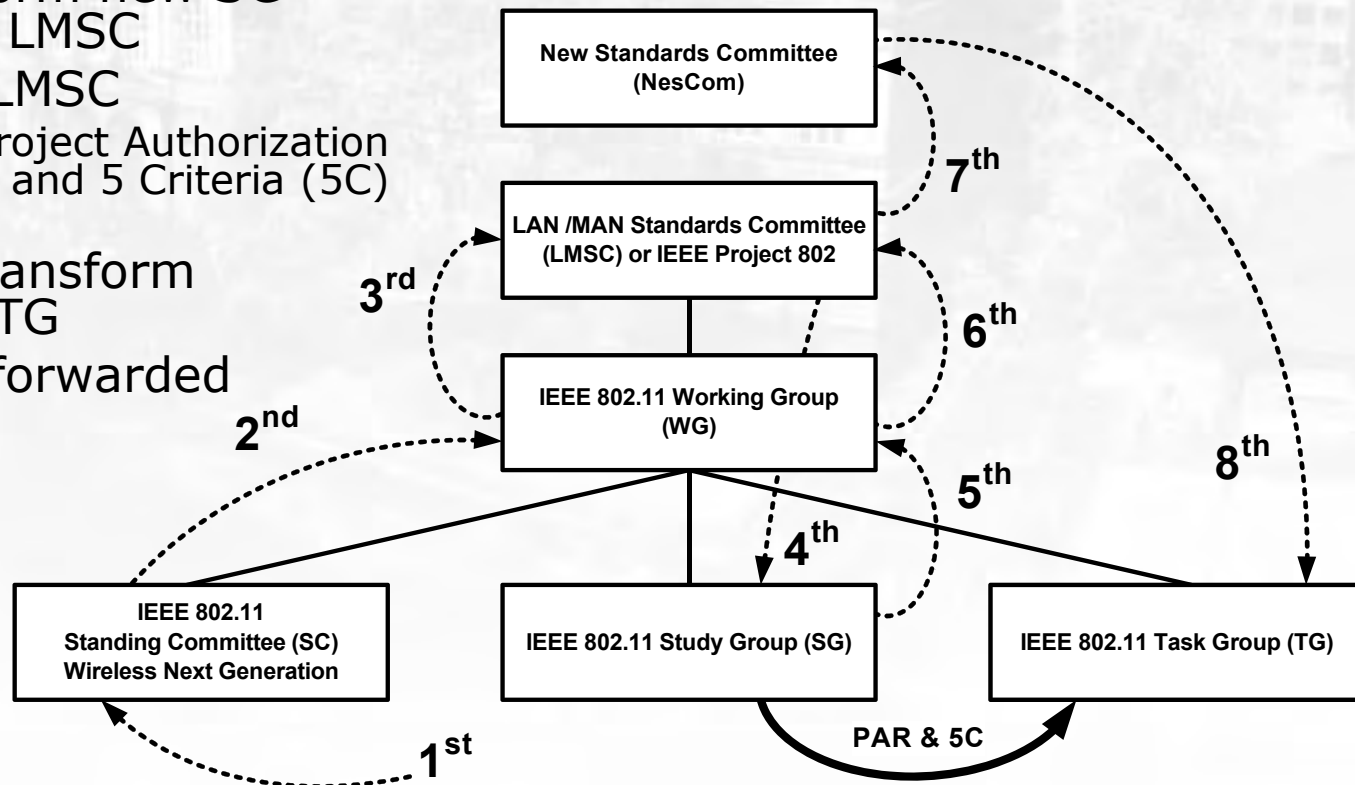
Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- 802.1
 - Higher Layer Local Area Networks (LAN) Protocols
- 802.3
 - Ethernet
- 802.11
 - Wireless Local Area Networks (LAN)
- 802.15
 - Wireless Personal Area Networks (PAN)
- 802.16
 - Wireless Metropolitan Area Networks (MAN)
- 802.17
 - Resilient Packet Ring
- 802.18
 - Radio Regulatory TAG
- 802.19
 - Coexistence TAG
- 802.20
 - Mobile Broadband Wireless Access (MBWA)
- 802.21
 - Media Independent Handoff
- 802.22
 - Wireless Regional Area Networks (WRAN)

The way to approval

Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

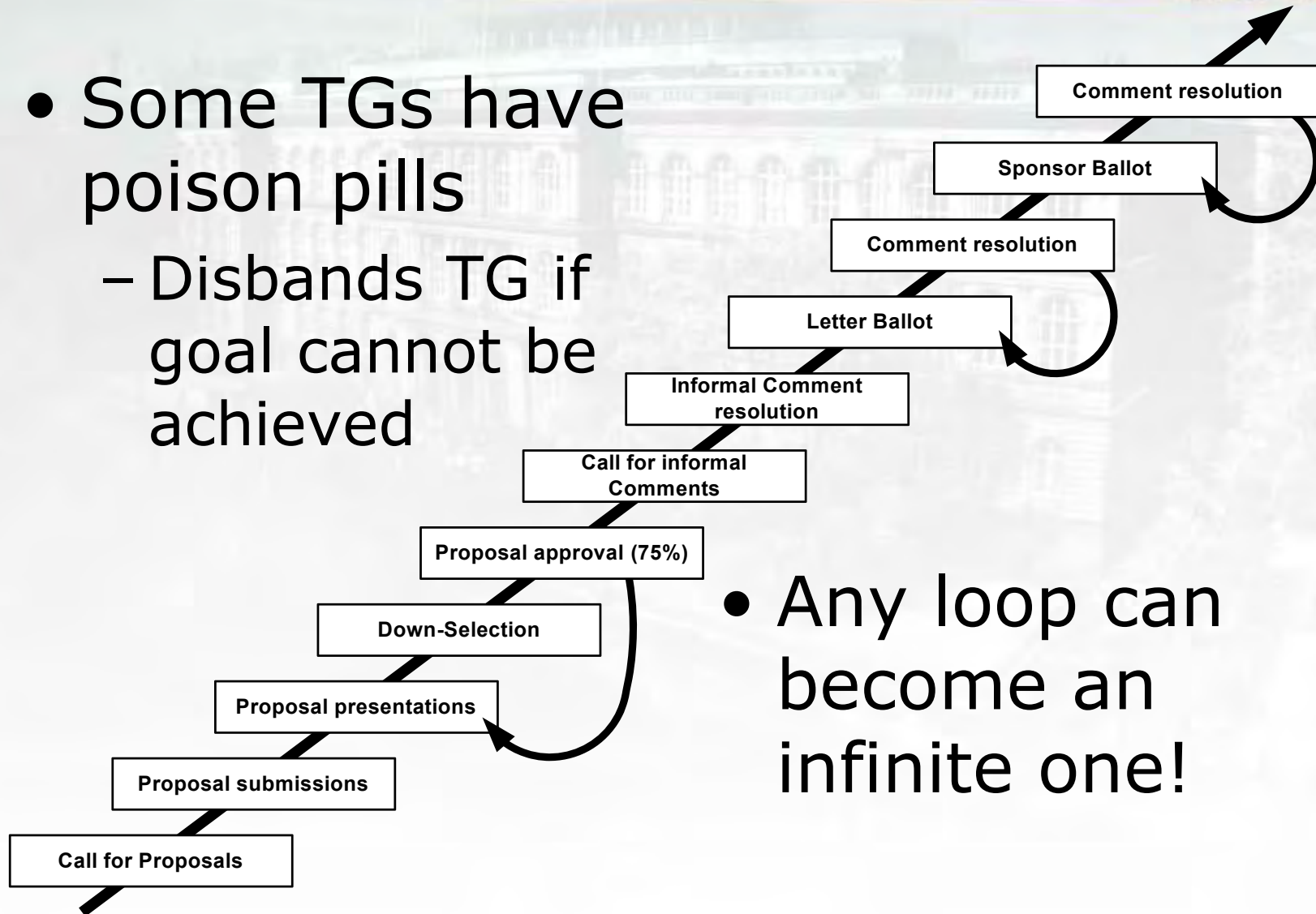
1. Interest presentation at SC WNG
2. Formation of new SG proposed to WG by SC WNG
3. Proposal to form new SG forwarded to LMSC
4. Approval by LMSC
 - SG develops Project Authorization Request (PAR) and 5 Criteria (5C) documents
5. Request to transform SG into new TG
6. TG proposal forwarded LMSC
7. TG proposal forwarded to NesCom
8. Approval by NesCom



Progress in the Task Group (TG)

Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- Some TGs have poison pills
 - Disbands TG if goal cannot be achieved



- Any loop can become an infinite one!

Wireless Mesh Networks in the 802

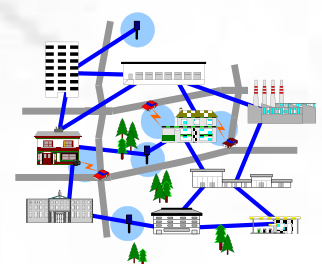
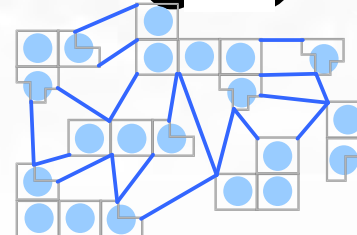
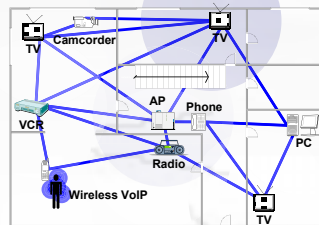
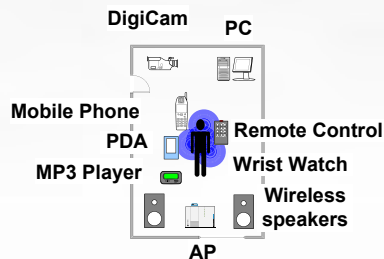
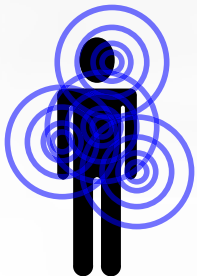
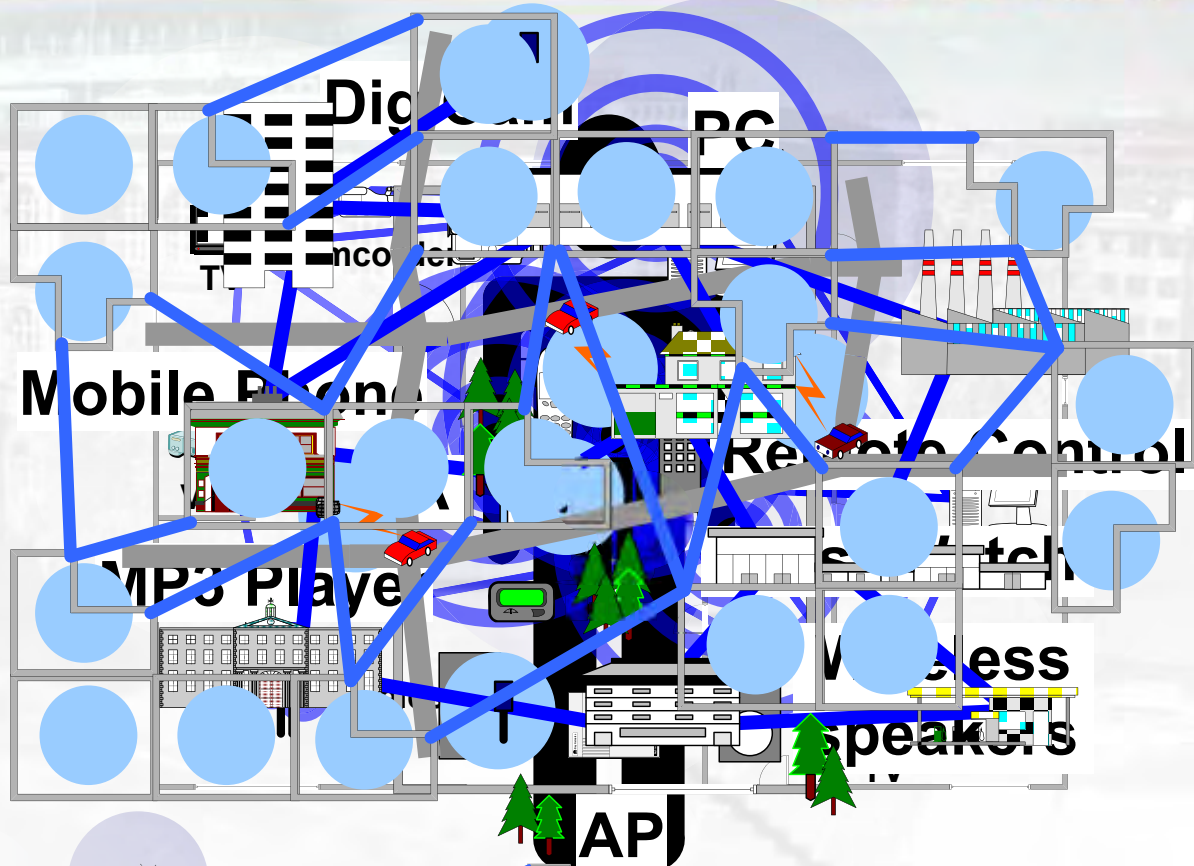
Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

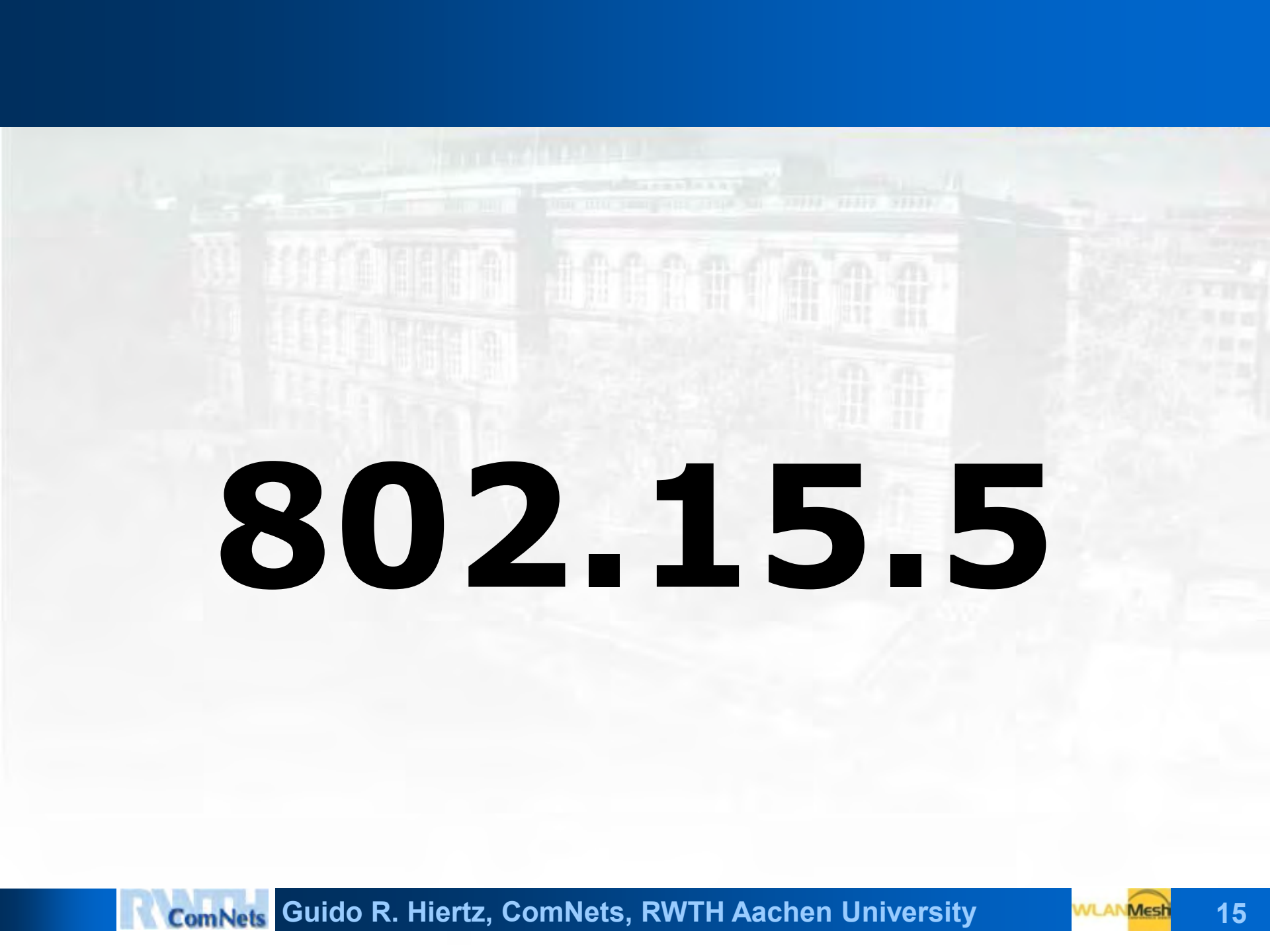
- IEEE 802.11s
 - Wireless LAN Mesh
- IEEE 802.15.5
 - Wireless PAN Mesh
- IEEE 802.16j
 - Mobile Multihop Relay

Active Mesh Task Groups in the LMSC

Overview – **IEEE** – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- WPAN, 802.15.5
 - Body
 - Single room
- WLAN, 802.11s
 - Apartment
 - Office
 - Campus
 - Street
- WMAN, 802.16
 - City





802.15.5

802.15.5 – WPAN Mesh

Overview – IEEE – **802.15.5** – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- Task Group since January 2004
 - Independent of 802.15.3 (high speed) & 802.15.4 (low speed)
 - Considering compatibility
- Devices for mass market
 - “Bluetooth-like”
 - Sensor networks
- Enhanced reliability
 - Route redundancy
- Simple deployment/configuration
 - Network coverage extension
- Extended device battery lifetime



802.15.5 – Design goals

Overview – IEEE – **802.15.5** – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- Addressed topics
 - MAC enhancements
 - Routing
 - Security
- Low speed applications
 - Large scale sensor networks
- Simple deployment
- High speed applications
 - Streaming
 - Video
 - Audio
 - Consumer Electronics
 - VoIP

802.15.5 – Current status

Overview – IEEE – **802.15.5** – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- Draft candidate since 2006-03
 - Since then, no additional substantial contributions received
 - Overlay to centralized 802.15.3 MAC
 - Borrowing ideas from ECMA-368
 - Decentralized
 - Tree based path selection
- Lost significance since 802.15.3a (Ultrawideband PHY for WPAN) dissolved
- Dominating external alliances
 - WiMedia Alliance (high speed UWB)
 - Bluetooth SIG
 - ZigBee Alliance (low speed, sensor networks)

WiMedia Alliance – Ultrawideband WPAN

Overview – IEEE – 802.15.5 – **WiMedia** – 802.11s – Wi-Fi – 802.16j – WiMAX – Summary

- FCC decision in February 2002
 - Overlay technology
 - Reusing assigned spectrum
 - 3.1-10.6 GHz
 - 528MHz channels
 - Extremely low transmission power
 - No interference to existing services
- 802.15.3a (UWB PHY) proposal
 - Multiband OFDM Alliance (MBOA)
 - Multiband OFDM PHY
 - Competing with UWB Forum
 - Direct Sequence (DS) UWB
- WiMedia defines MAC & PHY
 - MAC never proposed to IEEE
 - Ratified standards
 - ECMA 368 & 369
 - ISO/IEC 26907 & 26908
 - Baseline for other alliances
 - Bluetooth SIG
 - Bluetooth 2.0
 - USB Implementers Forum
 - Certified Wireless USB
- WiMedia may introduce Mesh in future
 - Modern MAC design



802.11s

802.11s – WLAN Mesh

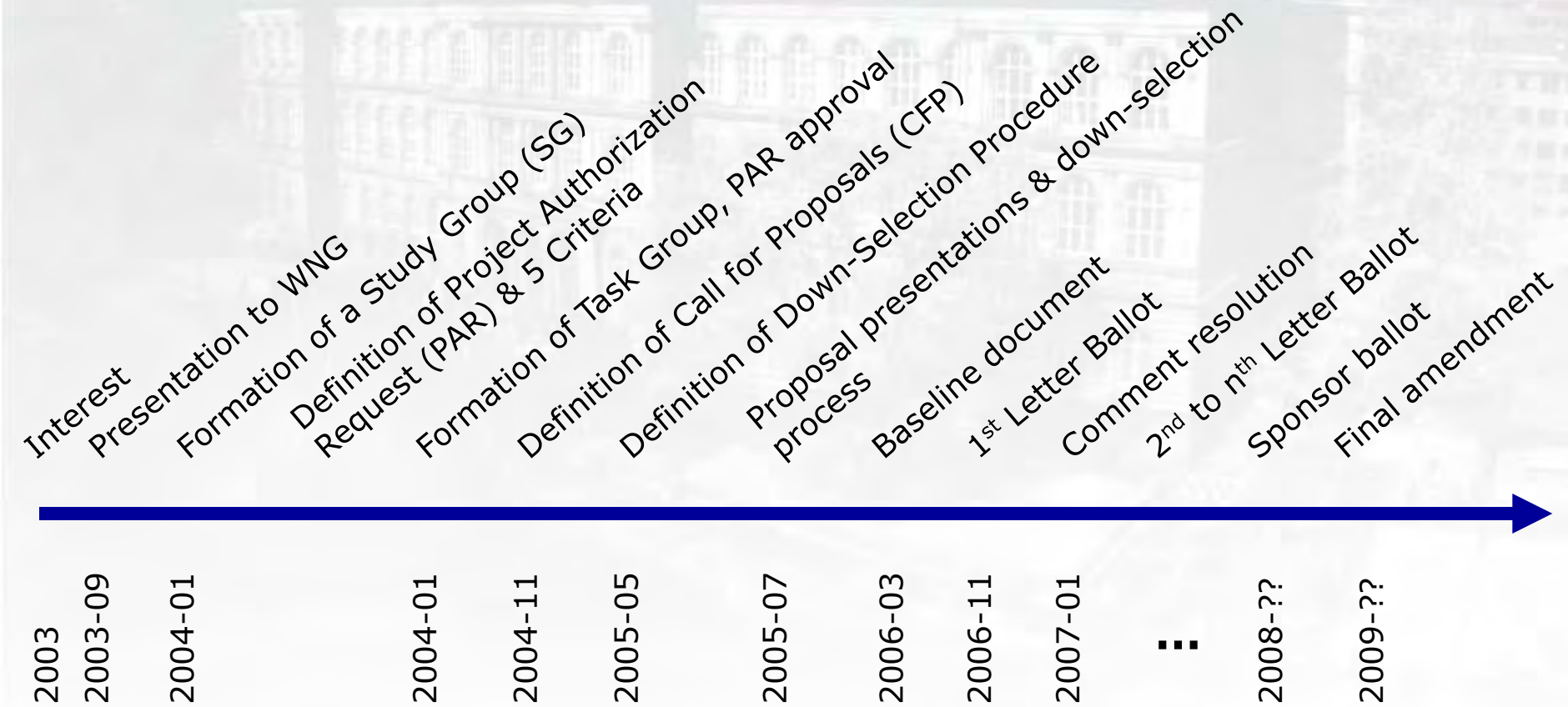
Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- Most mature Mesh standard in 802
 - Defines new entity class: Mesh Point
 - Mesh Point can be colocated with other 802.11 entities
 - Mesh Access Point,
 - Mesh Point Portal
 - ...
- Seamless integration with any 802 network
 - Support for uni-, multi- & broadcast traffic
- Wide range of applications
- Fully decentralized



IEEE 802.11s progress

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary



Roots of the 802.11s Draft 1.01

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- July 2005 meeting
 - Low hurdle vote
 - 15 proposals submitted
 - 3 eliminated
- September 2005 meeting
 - 6 mergers
 - 2 eliminated
- November 2005
 - 3 full proposals
 - 1 merger
 - 1 eliminated
- January 2006
 - Merger of final proposals (Wi-Mesh Alliance & SEE-Mesh)
 - Baseline
 - Draft

Project Authorization Request & Usage scenarios

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j - WiMAX - Summary

1. The proposed amendment shall be **an extension to the IEEE 802.11 MAC**.
 2. The amendment will define an architecture and protocol for providing an IEEE **802.11 Mesh** [...]
 3. [...] over self-configuring **multi-hop** topologies.
 4. A **Mesh is functionally equivalent to a wired ESS**, with respect to the STAs relationship with the BSS and ESS.
 5. A **target configuration is up to 32 devices** participating as forwarders in the Mesh.
 6. The **amendment shall utilize IEEE 802.11i** security mechanisms, or an extension thereof
 7. [...] in which all of the stations are **controlled by a single logical administrative entity** for security.
 8. The amendment shall allow the use of **one or more IEEE 802.11 radios** on each station in the Mesh.
- Usage scenarios
 - Military
 - Battlefield communication
 - Public Safety
 - Emergency & disaster area communication
 - Residential
 - Consumer Electronics
 - Public Access
 - Provider operated networks
 - Office
 - Enterprise & business networks

Mesh WLAN – A multi level approach

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- Interworking with other networks
 - Integration into 802 “world”
 - Interfaces to higher layers
 - Broadcast traffic handling
 - Loop prevention
- Path selection concepts
 - Interface, selection information
 - Small scale Mesh WLAN
- MAC changes
 - Overcome multi hop limitations
- Multihop security
 - Extend 802.11i amendment
- Optional
 - Congestion & Call admission control
 - WLAN Mesh segregation
 - Channel measurements
 - 802.11 Task Group “k” concepts
 - Support Roaming stations (TGr)

WLAN Mesh and other 802 networks

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- IP layer blind for channel condition

→ **Path selection at MAC Layer**

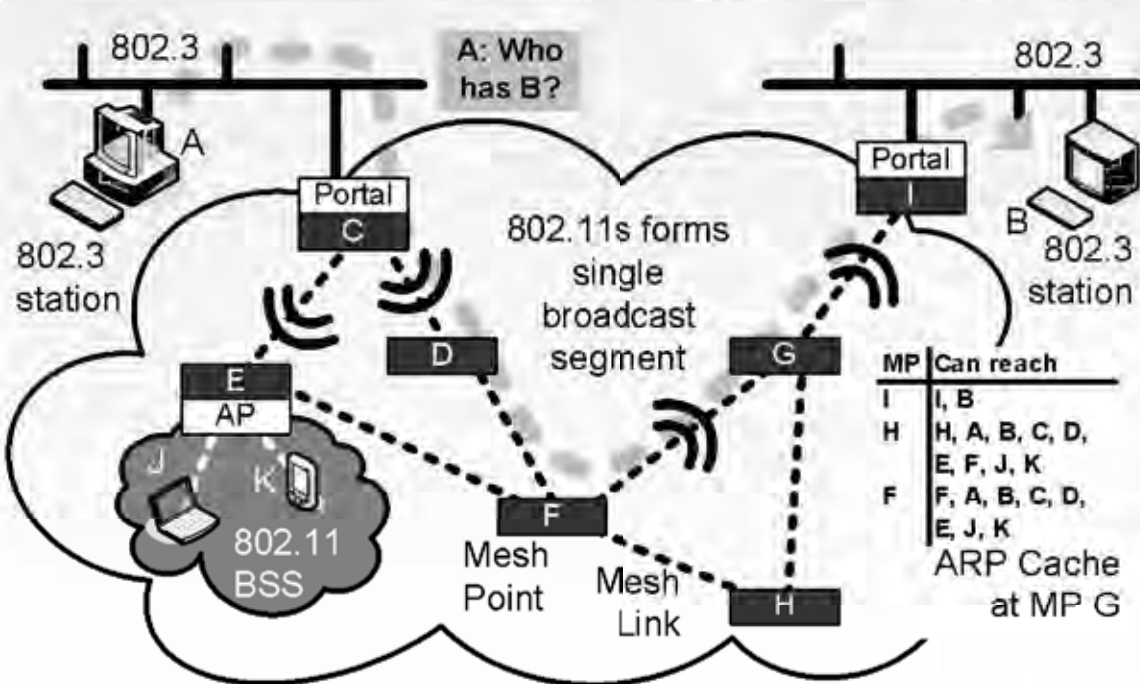
- 802.11 Wireless Distribution System

– Mesh WLAN must be transparent for

- Stations
- Higher layers
 - Important protocols:

» DHCP
» ARP

- Seamless integration



802.11s – Path selection

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- Extended IETF MANET concepts
 - On-demand, proactive or hybrid routing

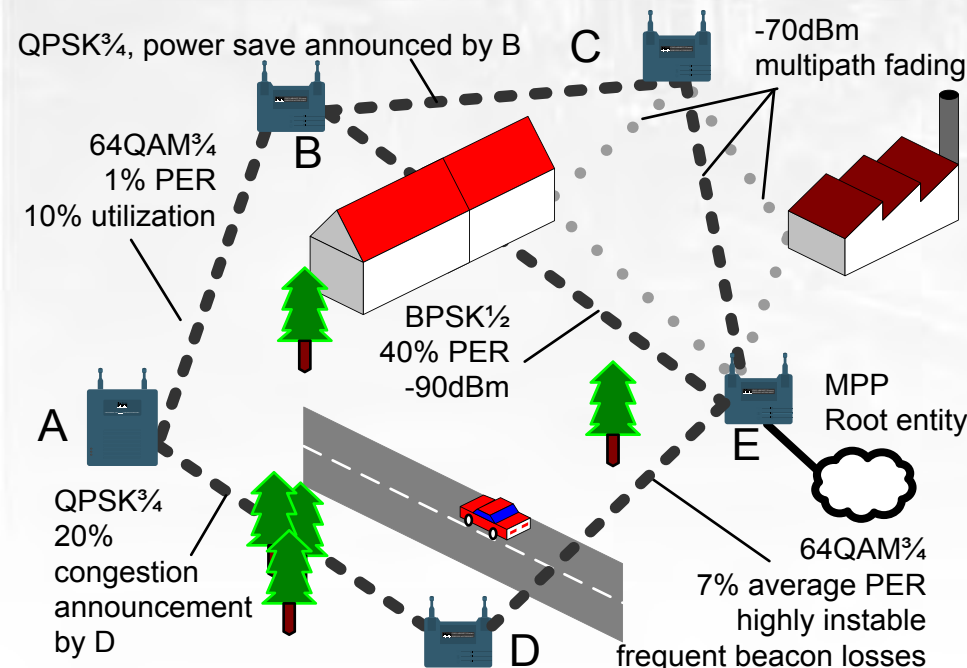
- Default: Hybrid Wireless Mesh Protocol
 - Optional: RA-OLSR

- Proprietary extensions possible

- Metrics

- PHY mode, Packet Error, Transmit power, hop count, link load etc.

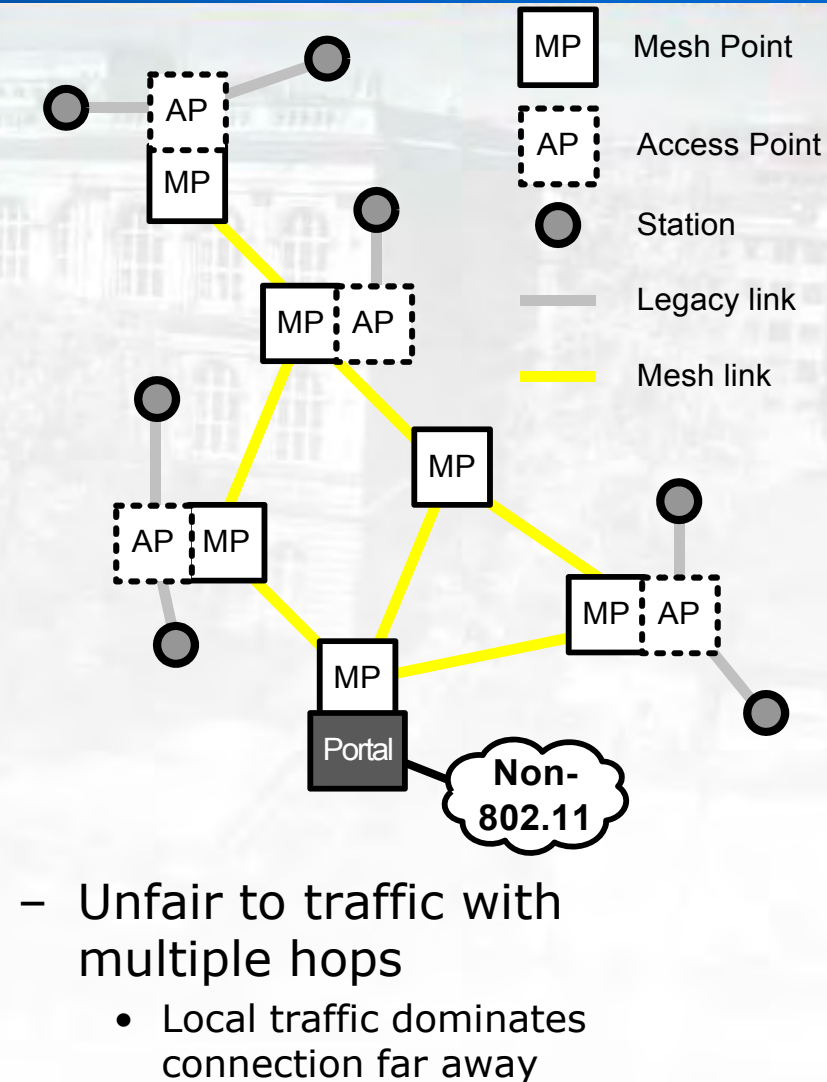
- Protocols



802.11s – Medium Access

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

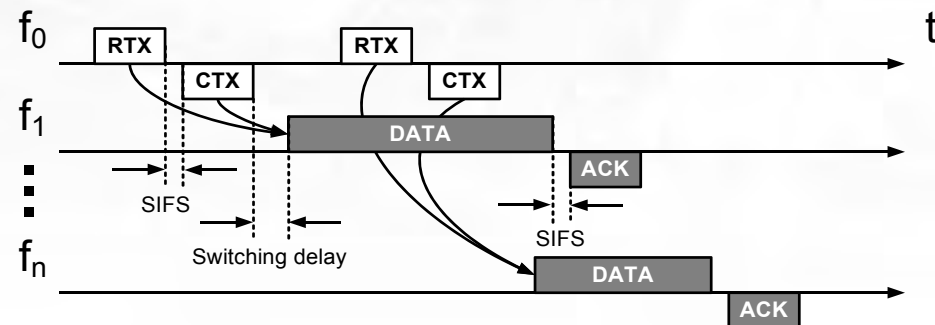
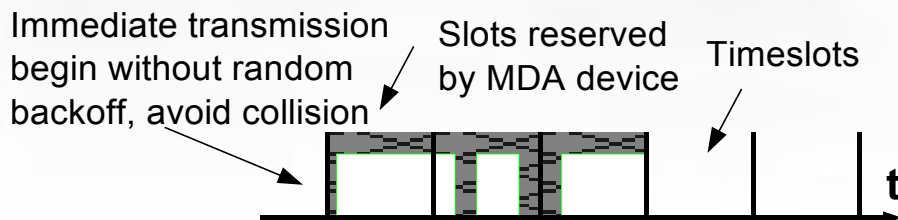
- Based on Enhanced Distributed Channel Access (EDCA)
 - Derived from 802.11e
 - Designed for single-hop
 - Poor performance in Mesh
 - Inefficient in overlapping network conditions
 - Local and Mesh traffic equal
 - No spatial frequency reuse possible
 - Mesh and stations equally compete on medium access
 - No priority to Mesh possible



802.11s – Optional Medium Access enhancements

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- Mesh Deterministic Access (MDA)
 - Flexible medium reservation
 - Enables QoS support
 - Reduces contention
 - Increased efficiency
 - 1st Mesh aware MAC in 802
- Common Channel Framework (CCF)
 - Removed from current draft
 - Uses orthogonal channels
 - Switching technology
 - Exploit additional capacity



802.11s – Security aspects

Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- Difficult subject
 - Protection against Denial-of-Service hardly possible in wireless
 - Single compromised entity threatens whole Mesh
- 802.1x
 - Central Authentication Server
- Pre-shared keys
- 4-way handshake
 - 802.11i defines supplicant & authenticator
 - Mesh Points change roles
- Per link security
 - No End-to-End security
 - IPsec for tunnels
- Key revocation
 - Exclude compromised Mesh Points

One Laptop per Child (OLPC) – 1st 802.11s implementation

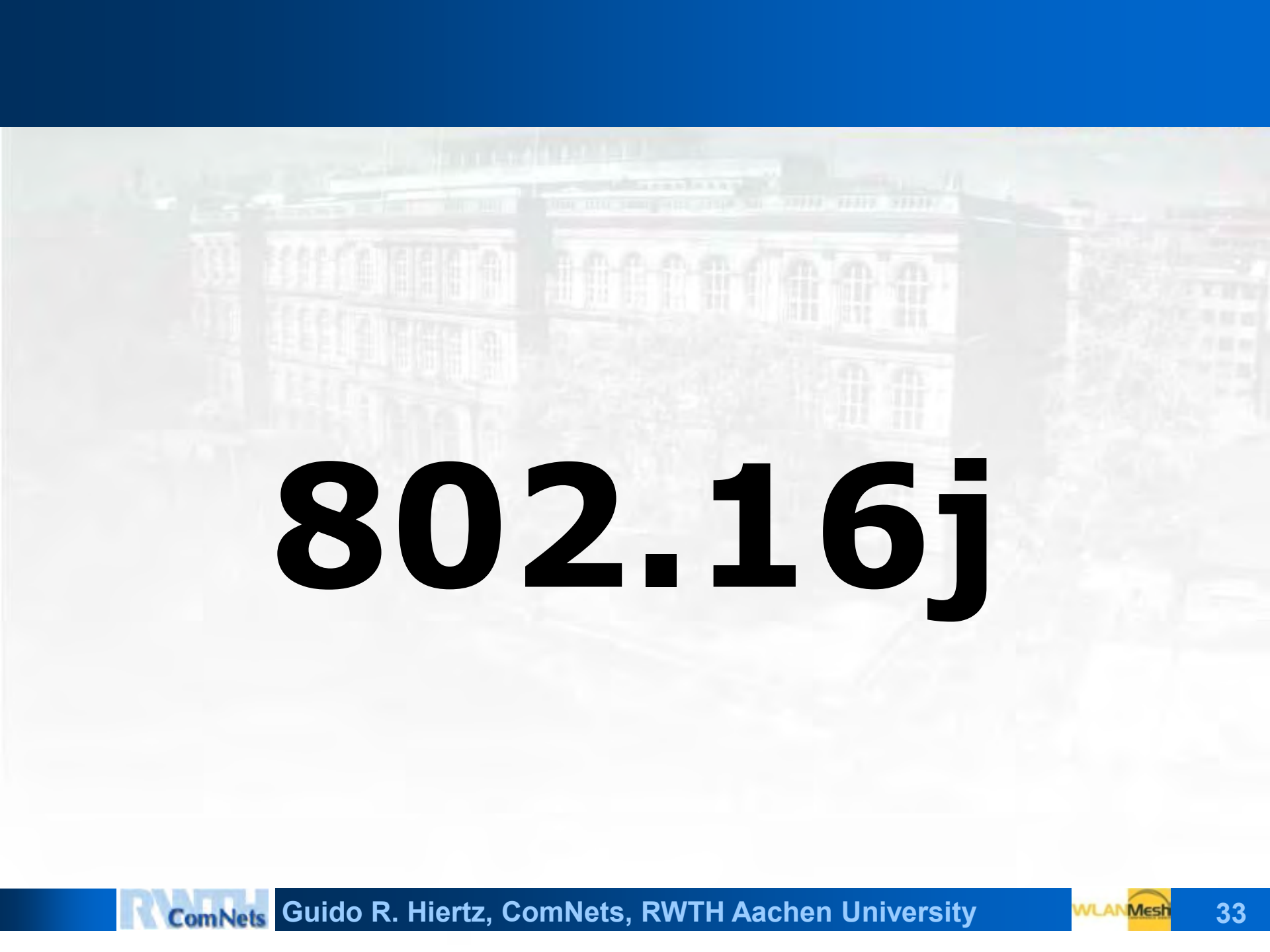
Overview – IEEE – 802.15.5 – WiMedia – **802.11s** – Wi-Fi – 802.16j – WiMAX – Summary

- Aka 100\$ laptop
- All Open Source
 - Except Firmware for Marvell 802.11 chipset
 - Mesh code available
- Partially implements 802.11s-D1.0
 - HWMP without tree based routing
 - AODV mature and reliable
 - Operates simultaneously as Station and Mesh Point
 - WLAN chipset independent of main CPU
 - WLAN Mesh operates when laptop in doze mode



- WFA has huge market impact
 - Test plans, Interoperability & Certification
 - Ease of use experience for Customers
 - “Wi-Fi certified makes it Wi-Fi” ...
- Mesh Marketing Task Group since October 2006
 - Working on Usage scenarios
 - May re-define mandatory/optional parts





802.16j

802.16 – Mesh Mode

Overview – IEEE – 802.15.5 – WiMedia – 802.11s – Wi-Fi – **802.16j** – WiMAX – Summary

- 802.16 modes
 - Point-to-Point
 - Not specified
 - Point-to-Multipoint
 - No known implementation
 - Mesh
 - Centralized and decentralized
- Mesh mode
 - Up- & Downlink schedule to be aligned
 - Poor description in standard
 - To be removed from standard with future revision

802.16j – Mobile Multihop Relay (MMR)

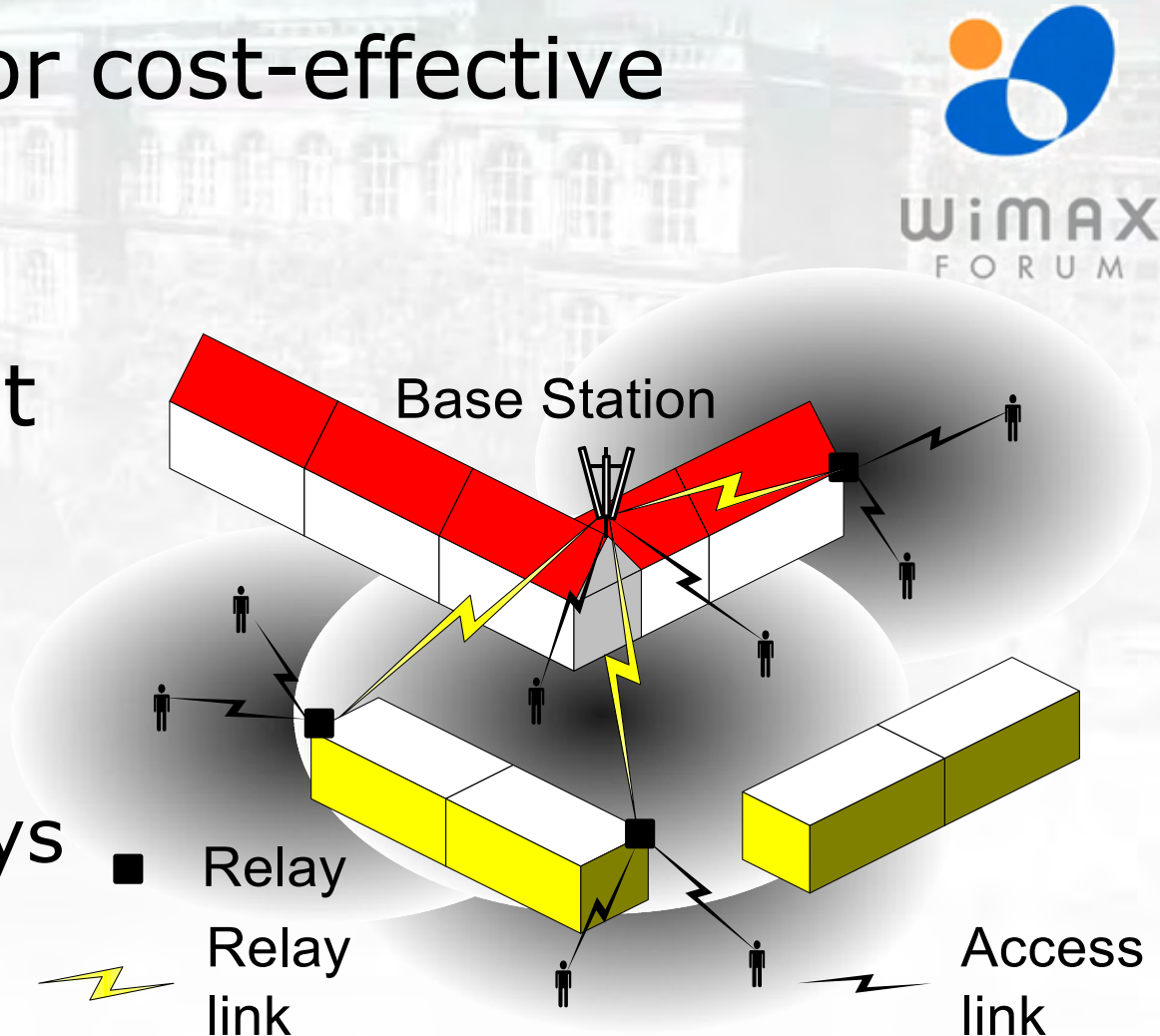
Overview – IEEE – 802.15.5 – WiMedia – 802.11s – Wi-Fi – **802.16j** – WiMAX – Summary

- Base station (BS) controls relays
 - Fixed
 - Relays under control of network operator
 - Nomadic & mobile relays
 - Military applications
 - Support for moving vehicles (bus line etc.)
 - Devices not necessarily under control of operator!
- Relays operate as proxy
 - On behalf of BS
- Full control over network
- Centralized structure
- High market potential
 - Simplifies roll-out

Relay based WiMAX

Overview – IEEE – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – **WiMAX** – Summary

- Essential for cost-effective roll-out
- Easy deployment
- Simple coverage extension
 - Fixed relays



Comparison of 802 Wireless Mesh Networks

Overview – IEEE – 802.15.5 – WiMedia – 802.11s – Wi-Fi – 802.16j – WiMAX – **Summary**

	802.11s	802.15.5	802.16j
Performance	Low	High	Medium
Market potential	High	Low	High
Coverage	Residential to Community	Residential	Community to Urban
Current status	Preparing 2nd draft	Pre-mature	Developing baseline draft
Projected completion date	2007-01 (PAR amendment: 2009-01)	2006-12	2007-09
802 approved until	2008-12-31 (PAR amendment: 2010-12-31)	2008-12-31	2010-12-31
Topology	Any	Any	Star (Relay based)
Target market	CE, Military, Public safety, residential, office, community	CE, residential	Fixed Infrastructure, fixed in building, temporary, nomadic on mobile vehicle
QoS support/ guarantee	Not possible (EDCA) Likely (MDA)	Possible	All service level agreements

- Mesh technology
 - Overcome limited ranges @ high speed
 - Important for any future wireless system
 - Cost-effective deployment
 - Enabling wireless next generation
 - IEEE 802 enables Mesh market

Questions are welcome!



Thank you for your attention !

Guido R. Hiertz
hiertz@ieee.org

References

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- <http://ieee802.org/802%20overview.pdf>
- 11-07-0149-05-000s-modified-802-11-tgs-par-and-5c.doc
- IEEE P802.11s/D1.01, March 2007
- [IEEE 802.16j-06/015](#)
Harmonized Contribution on 802.16j Usage Models
- <http://standards.ieee.org/board/nes/projects/802-16j.pdf>
- <http://standards.ieee.org/board/nes/projects/802-15-5.pdf>
- <http://standards.ieee.org/board/nes/projects/802-11s.pdf>

Pictures

- Page 6: Ethernet diagram drawn by Robert M. Metcalfe, photographed by Dave R. Boggs, 1976,
http://ieee802.org/3/ethernet_diag.html
- Page 31:
http://wiki.laptop.org/go/Image:Green_and_white_machine.jpg, Fuse-Project, upload to OLPC-Wiki: OLPC user "Walter"