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Potentials and Challenges of Ad hoc and Mesh Networks

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ITG FG 5.2.4: Mobilität in IP-basierten Netzen

T Systems

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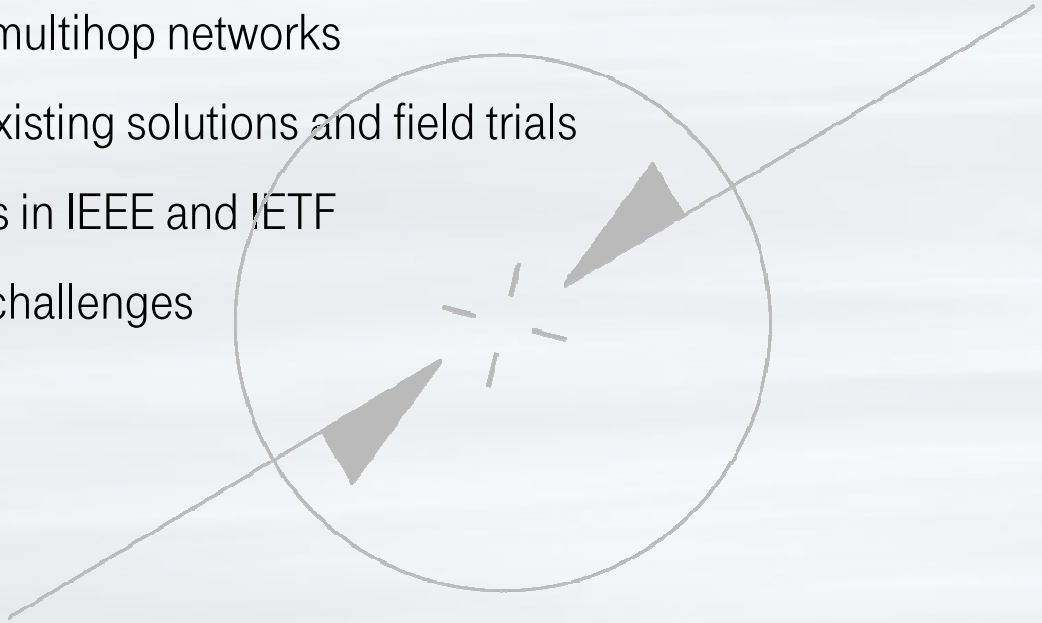
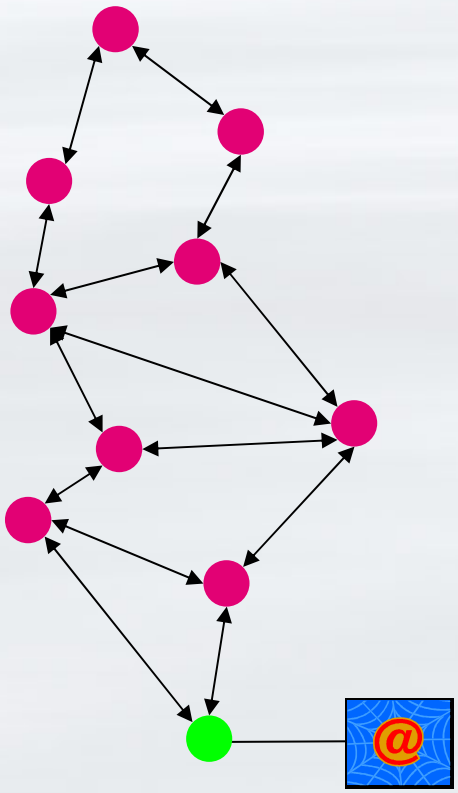
Potentials and Challenges of Ad hoc and Mesh Networks
Content

- Introduction to wireless multihop networks
- Application potentials, existing solutions and field trials
- Standardization activities in IEEE and IETF
- Research activities and challenges
- Conclusions

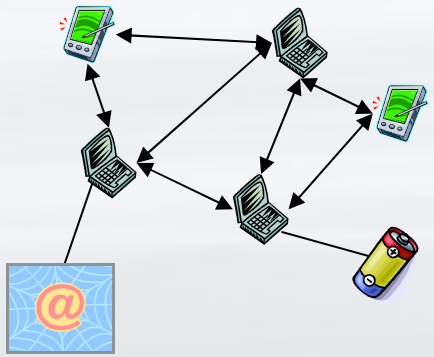


Wireless Multihop Networks
What is it?

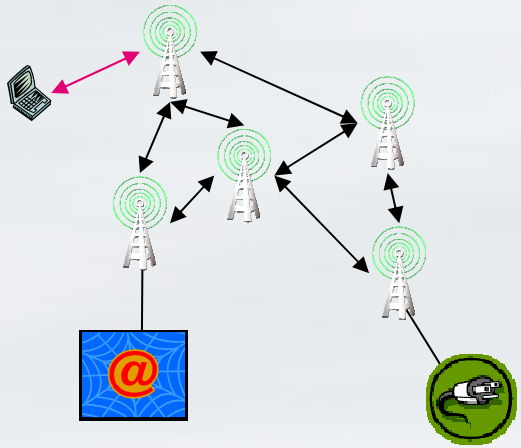


- Multipoint-to-Multipoint communication
  - Communication among nodes (direct or multihop)
- Every node in the multihop network has router functionalities
- Nodes are connected via wireless links
  - No wired connections
- Self-organizing - distributed intelligence
  - No centralized managing
  - Routing- und connection establishment are decided by every node itself
- Some of the nodes are connected to the Internet
  - Coverage of the Internet access is increased by other multihop nodes
- Multihop networks can be set up with various wireless technologies:
  - E.g.: Bluetooth, WLAN, WiMAX

Wireless Multihop Networks
Ad hoc/Mesh



- Mobile Ad hoc Networks (MANETs) – Client mesh networks
  - Spontaneous formed network that consists of mobile devices (PDA,Laptop)
    - High mobility
    - Limited energy
  - Mainly for local communication
    - Integration with external networks by means of special Gateways

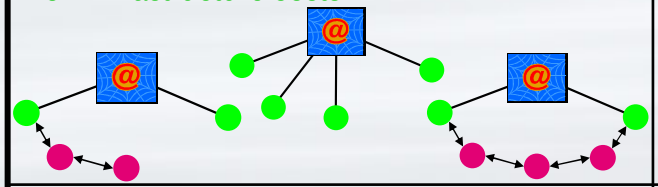


- Wireless Mesh Networks (WMNs) – Infrastructure mesh networks
  - Network consists of infrastructure components (e.g.: BS, AP)
    - Low mobility
    - Unlimited energy
  - Mostly used as transport network
    - Always connected to an external network (e.g. Internet)
    - Typically user access and backhaul communication are decoupled
      - E.g. backhaul via 802.11a and user access via 802.11b/g

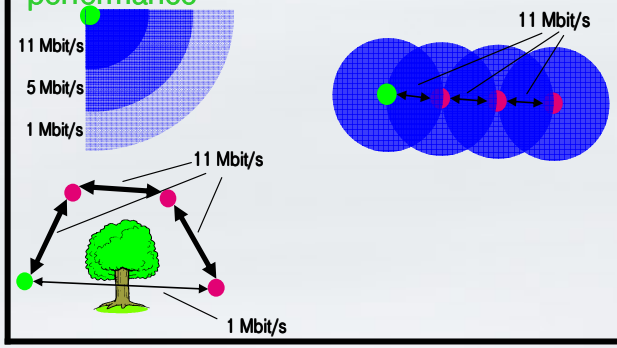
Today's focus!

Wireless Multihop Networks
Benefits of mesh multihop networks

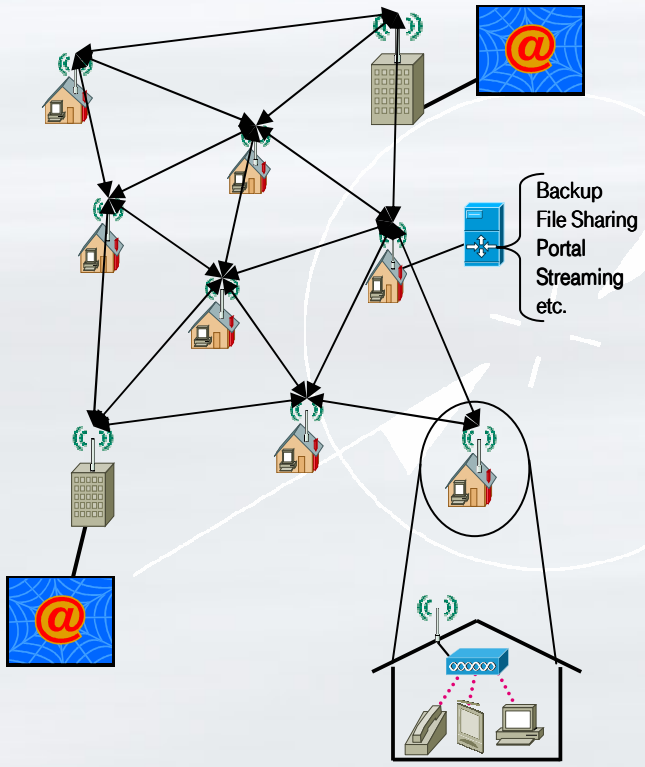
Attribute	Statement

Low infrastructure costs 	▪ Wiring is a cost intensive factor
	  ▪ Wiring each Internet access point is expensive
	▪ Mesh network can reduce the number of expensive Internet connections
	  ▪ Many mesh nodes share few Internet connections
	  ▪ Additional mesh nodes can be easy installed

Reliability and Robustness	▪ Redundant paths
Low transmit power	▪ Small distances between nodes ▪ Energy efficient, min. interference, spatial reuse
Easy extensible	▪ No wiring ▪ Autoconfiguration

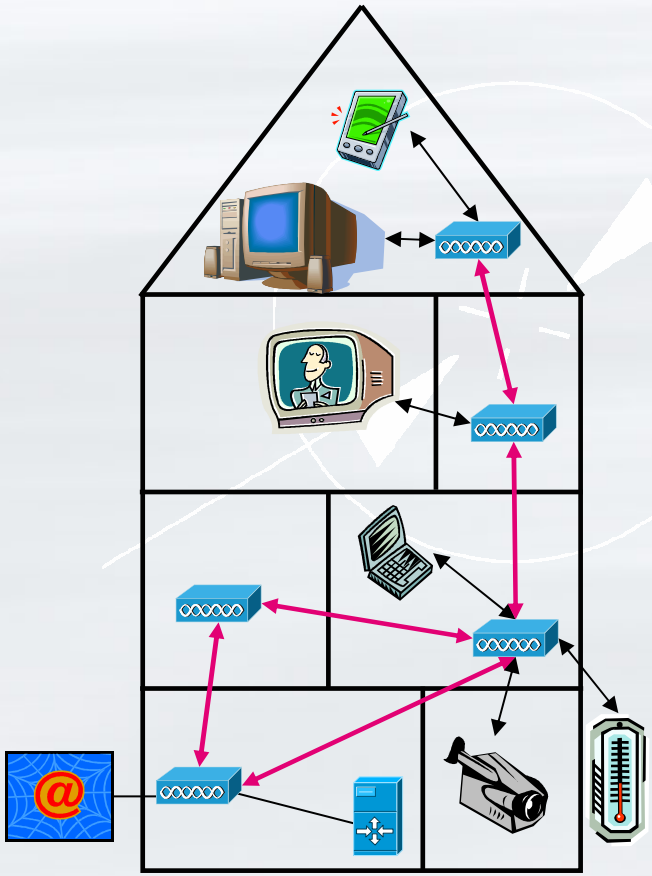
Coverage extension and enhanced performance 	▪ Multihop can enhance the coverage of a BS
	  ▪ Forwarding packets to the Gateway by intermediate nodes
	  ▪ Far users can be covered
	▪ Multihop can enhance the network performance
	  ▪ High performance for far users
	  ▪ Poor performance on direct link to the BS
	  ▪ Higher performance on short links
	  ▪ High performance for nodes without LOS
	  ▪ Direct link is poor because of obstacles
	  ▪ Routing around obstacles

Application Potentials of Mesh Networks
Broadband Wireless Internet Access (BWIA)



- Broadband access (e.g. DSL) is not available everywhere
  - Installing the required infrastructure is prohibitively expensive
- WMNs offer considerable advantages
  - Low Upfront Investments
    - No wiring
  - Customer Coverage
    - LOS to the BS is not required
  - Fast deployment
  - Reliability
    - No single point-of-failure
  - Optimized communication among mesh nodes
    - E.g. for community and neighborhood networking
- Application scenarios, e.g.:
  - Wireless DSL (e.g. WiMAX) to cover undersupplied DSL areas

Application Potentials of Mesh Networks
Indoor Networking



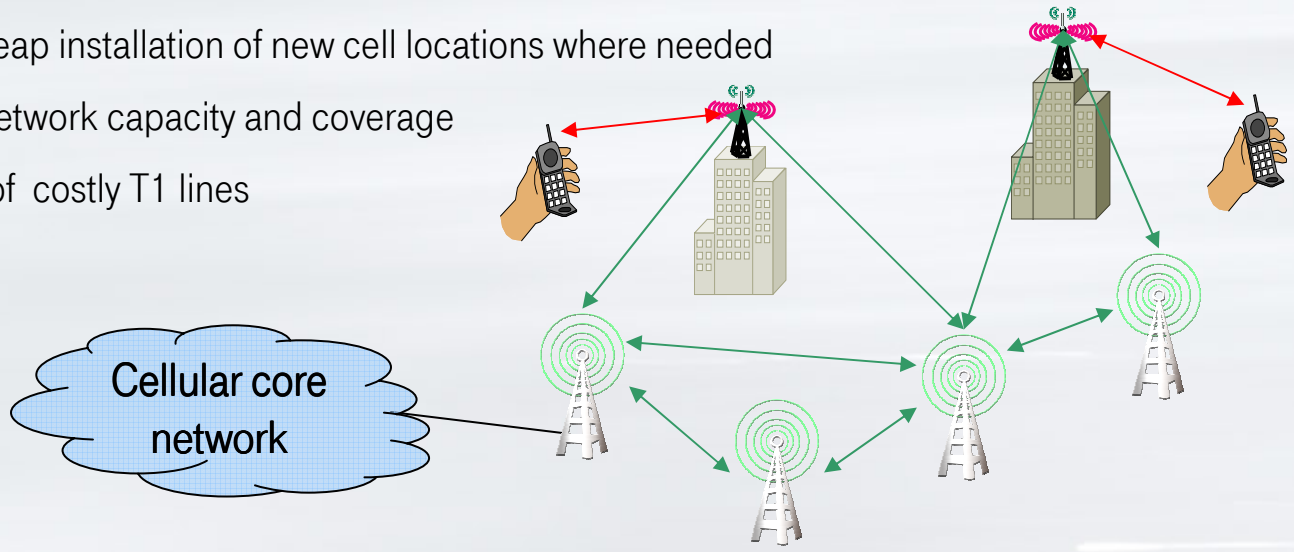
- Indoor coverage is difficult
  - Walls, objects, people, etc. interfere the propagation
  - Dead zones without coverage
  - Full coverage is expensive
    - Every AP needs an Ethernet connection to a central hub
- WMNs for indoor networking
  - All devices can share one Internet connection
  - Mesh APs only need power supply
- Application scenarios, e.g.:
  - Building automation
  - Broadband home networking
  - etc.

Application Potentials of Mesh Networks
Cellular backhaul

- Bandwidth demand is constantly increasing
  - Number of users increases
  - Superior multimedia services and applications
- Mesh networks to meet this demand

Cellular provider needs flexible network configuration

  - Flexible connection of cellular BSs to the core network via mesh connections
    - Flexible scaling and splitting of cells
  - Easy and cheap installation of new cell locations where needed
  - Increasing network capacity and coverage
  - Elimination of costly T1 lines

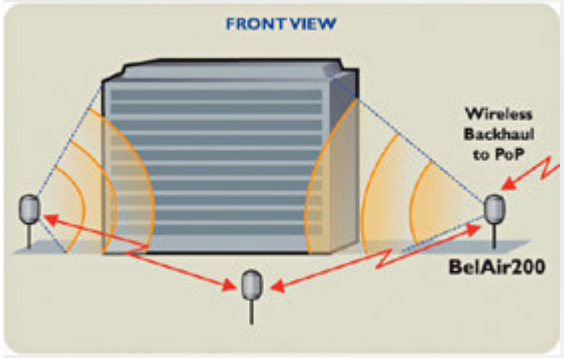


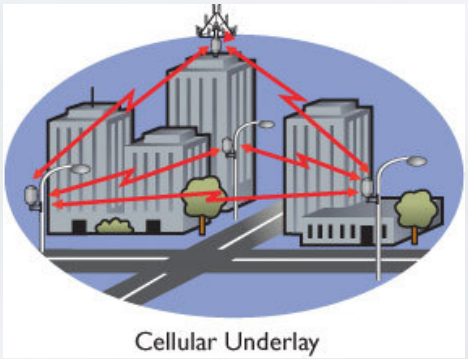
Application potentials of Mesh Networks
Further examples

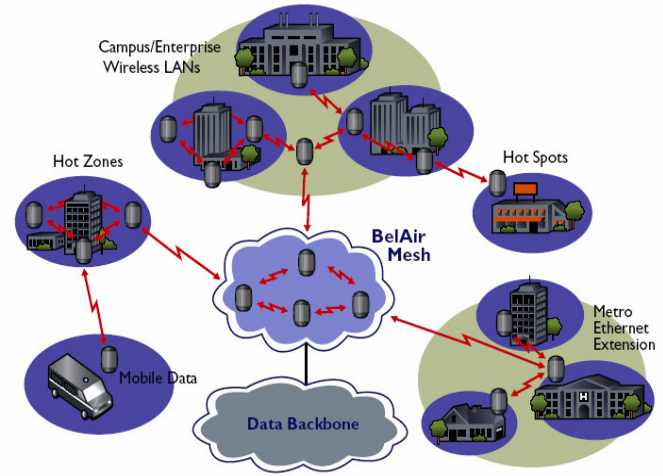
- Spontaneous (Emergency/Disaster) Networking
  - Communication infrastructure is destroyed or not existing
  - Spontaneous build WMN can be used for communication of the rescue team
- Security surveillance systems
  - WMNs are a much more viable solution than wired networks to connect all devices
  - Images and videos are the major traffic flow – high bandwidth
- Transportation environment
  - Mesh network beside railways to connect trains
  - Backhaul mesh network within the train to interconnect coaches
- Backhaul for Hotspots
- Car-to-Car communication
- Mobile user access

Existing Mesh Solutions
BelAir Networks

- Multiple Point-to-Point Mesh with WiFi Access to cover large venues
- Integrated wireless mesh backhaul and wireless access solution
  - User access via 802.11b/g (2.4GHz)
  - Backhaul connections via 802.11a (5GHz) – WiMAX in the future
- Enhanced wireless OSPF as routing protocol
- WiFi coverage inside buildings from the outside
- Cellular backhaul



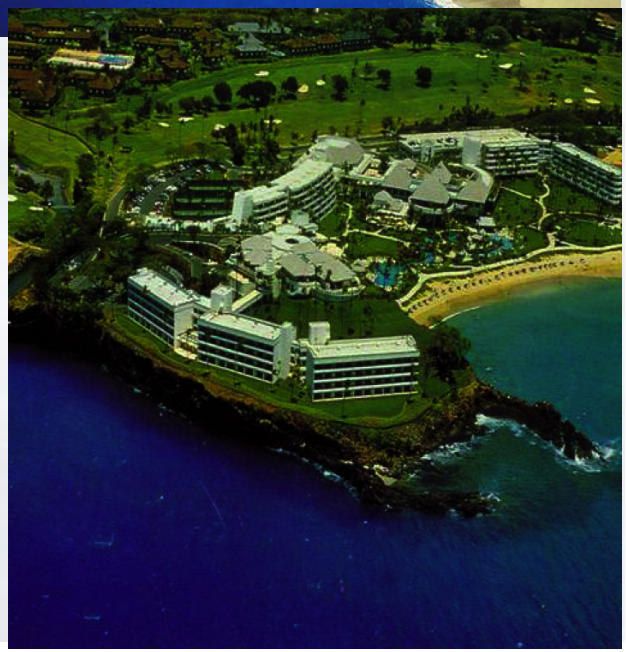




Source: BelAir networks, http://www.belairnetworks.com/

Existing Mesh Solutions
BelAir Networks
Deployment example: T-Mobile Meeting at Sheraton Maui

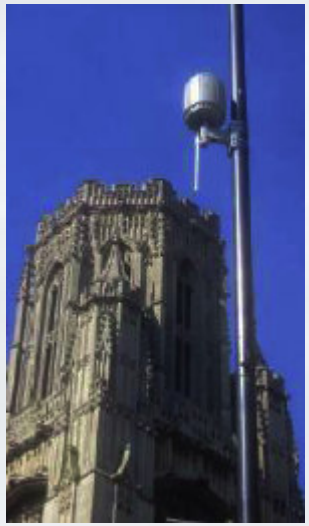
- Challenges:
  - 6 building complexes, 529 rooms, over 23 acres, including:
    - Fitness Center
    - Salon & Day Spa
    - 6 Restaurants and Bars
    - 6,500 square foot ballroom
    - 140 Yard Fresh Water Lagoon-Style Pool
  - Very limited room for deployment on the ocean side
  - Limited locations for mounting power access
- Result:
  - Full WiFi coverage of the Sheraton property (with only 13 mesh boxes)

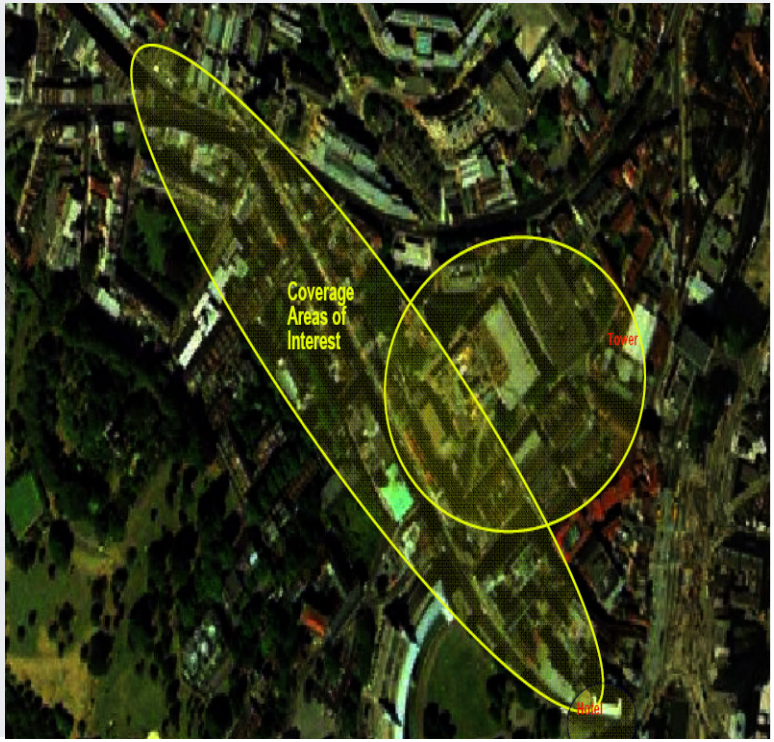


Source: BelAir networks, http://www.belairnetworks.com/

Existing Mesh Solutions
BelAir Networks
Deployment example: Telekom Ottawa

- Challenge:
  - Public WiFi access in downtown Ottawa
  - complete hotel coverage from the same mesh
- Result:
  - 20 BelAir mesh boxes to cover the desired area

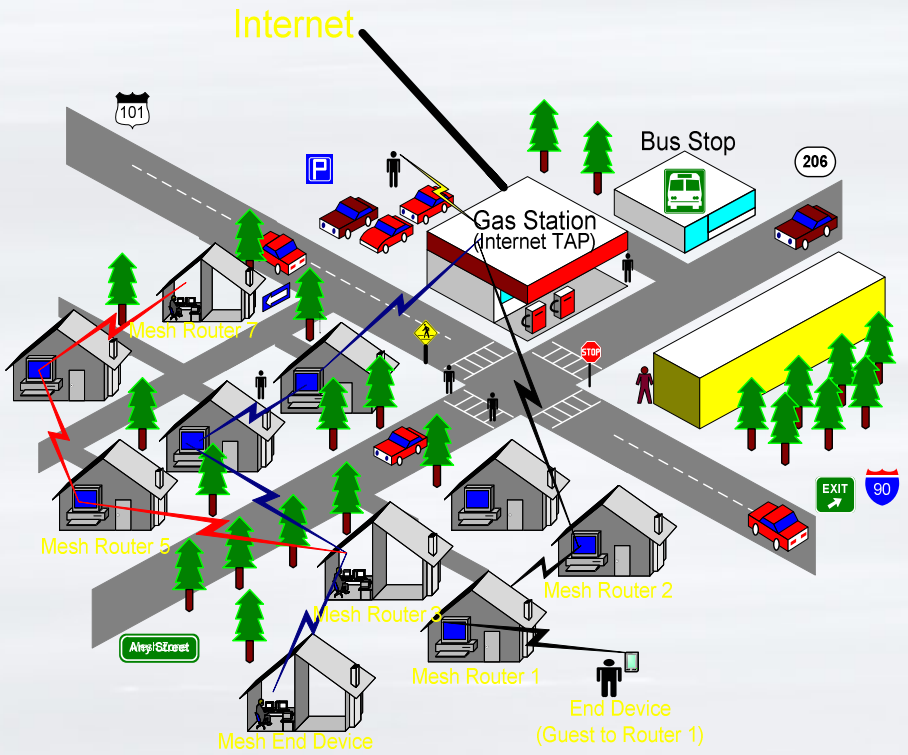




Source: BelAir networks, http://www.belairnetworks.com/

Existing Mesh Solutions
Microsoft

- Mesh connectivity layer (MCL) module
- Self-Organizing Neighborhood Wireless Mesh Networks
  - Fast and cost-effective sharing of Internet access via gateways that are distributed in the neighborhood
  - Neighbors can cooperatively deploy services (e.g.: backup technology)
  - Fast and easy dissemination of local information
    - Data must not go through a service provider and the Internet
- Microsoft focus on Software not Hardware
- Goal is to implement the multihop functionality in Microsoft Windows



Source: Microsoft, http://research.microsoft.com/mesh/

Existing Mesh Solutions

- Further proprietary mesh solutions are available from:
  - Nokia
  - Tropos
  - SkyPilot
  - Firetide
  - LocustWorld (Software)
  - etc.
  - Motorola
  - NovaRoam
  - 4G Systeme
  - Nortel Networks
- All these solutions rely on different technologies and standards
  - Thus they are all incompatible

Standardization is needed for mass market

Mesh Standardization Activities
IEEE

	802.11	802.15	802.16
Task Group	802.11s	802.15.4 (Zigbee) 802.15.5 (WPAN Mesh)	802.16-2004 (802.16a)
Network type	Local Area networks	802.15.4: Sensor networks 802.15.5: Personal area networks	Metropolitan area networks
Focus	Phy & Mac layer	Phy & Mac layer	Phy & Mac layer
Dates	First meeting 06/2004	802.15.4 standardized 11/2003 802.15.5 05/2004	802.16a ratified in 01/2003
Current state	Begin of standardization process: Review of proposals Creation of joint proposal by the end of 2006 Standard is targeted to be approved by 2008	802.15.4: native mesh support 802.15.5: Begin of standardization process: determine the necessary mechanisms (in PHY & MAC) WPANs to enable mesh netw.	Mesh already included in the current (802.16-2004) standard – many limitations and open issues Proposals have been submitted to enhance the 802.16 mesh New Study Group to discuss about Mesh or Relay approach

Mesh Standardization Activities
IETF

- A lot of effort has been spend on developing multihop routing protocols
  - E.g.: AODV, DSR, DSDV, etc.
- These protocols are designed for mobile ad hoc networks (MANETs) and thus optimized for:
  - High mobility and dynamic networks
  - Less overhead and energy efficient
  - Low bandwidth
- These protocols need to be optimized for WMNs
  - Many optimization possibilities
- Currently no standardization activity specialized on mesh routing protocols

Research activities and challenges

Multihop Routing

- Route selection
  - Most of the current protocols only consider hop count as metric
  - Further possible metrics: traffic situation, delay, jitter, bandwidth, link quality, error rate, etc.
- Load balancing
- Backup routes
- Routing Security
  - Protect against routing attacks
  - Protect against forwarding attacks

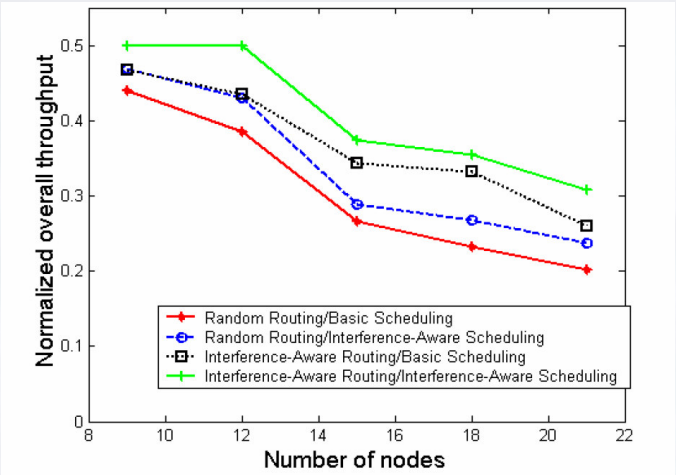


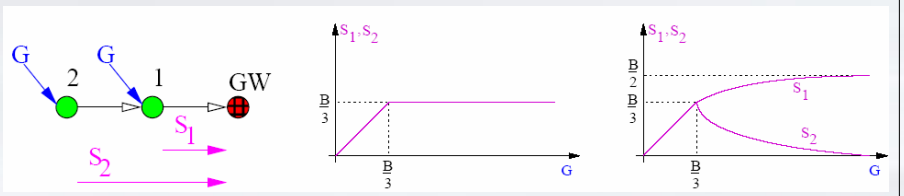
Figure 7. Throughput performance of a random topology 802.16 mesh

Source: Hung-Yu Wei, et al. "Interference-Aware IEEE 802.16 WiMax Mesh Networks"

Research activities and challenges (Cont.)

Quality of Service

- Resource reservation
  - Wireless channel problematic – fast changing wireless conditions
  - Multihop
- Resource allocation (Scheduling)
  - Fairness
  - Spatial reuse
  - Interference avoidance
  - Actual channel conditions
- Capacity enhancement on PHY layer
  - Directional and smart antennas
  - MIMO systems
  - multi-radio/multi-channel systems



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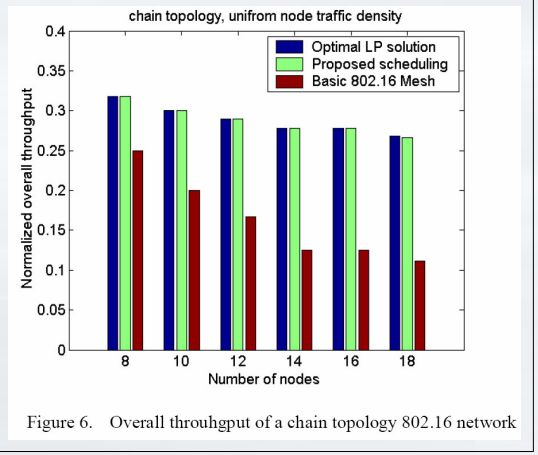

Figure 6. Overall throuhgput of a chain topology 802.16 network

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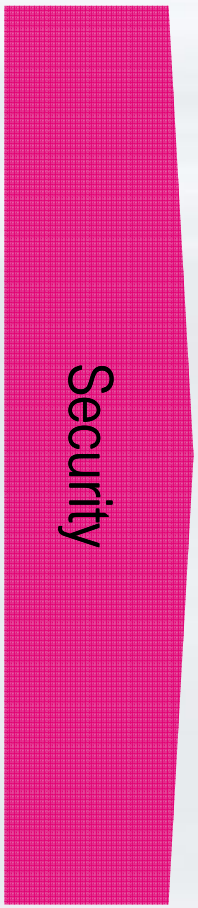
*Source: Jangeun Jun, et al. "The Nominal Capacity of Wireless Mesh Networks"
**Source: Hung-Yu Wei, et al. "Interference-Aware IEEE 802.16 WiMax Mesh Networks"

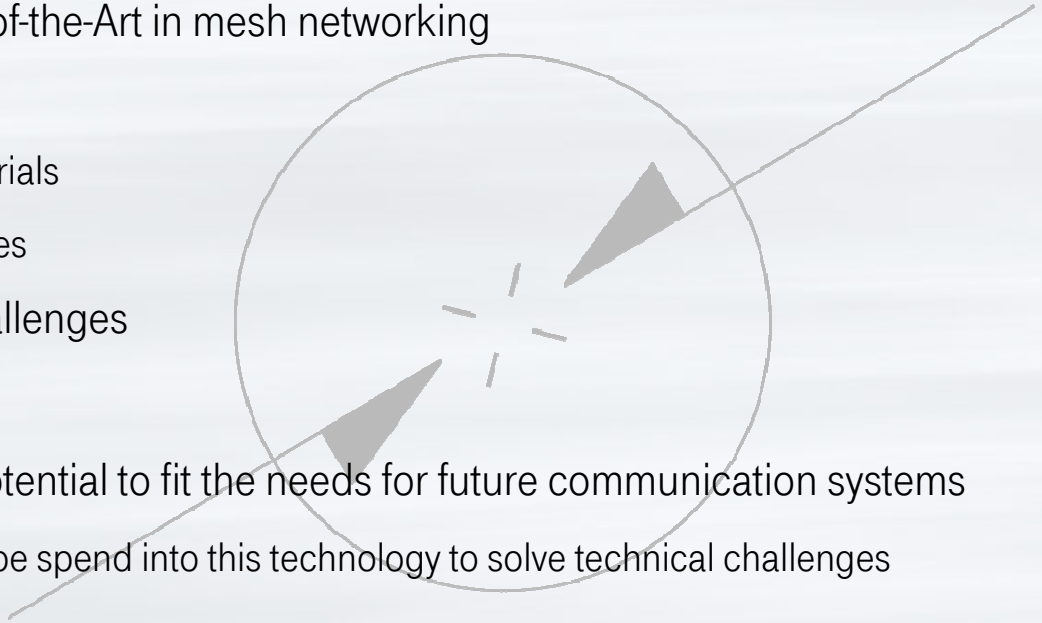
Research activities and challenges (Cont.)



- Attacks are simplified because of wireless medium – security should guard against:
  - Malicious users (and freeloaders)
  - Routing attacks
    - Changing of routing tables by misuse of routing messages
  - Forwarding attacks
    - Creation of Wormholes
  - Guard against MAC attacks
    - Congestion of network by malicious users
- No centralized Management
  - Distributed key management
  - Distributed AAA functionalities

Conclusions

- An overview about multihop networks was presented
- Introduction into the State-of-the-Art in mesh networking
  - Applications scenarios
  - Existing solutions and trials
  - Standardization activities
- Research activities and challenges



- Mesh networks have the potential to fit the needs for future communication systems
  - A lot of effort needs to be spend into this technology to solve technical challenges

Contact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