Wireless Mesh Networks

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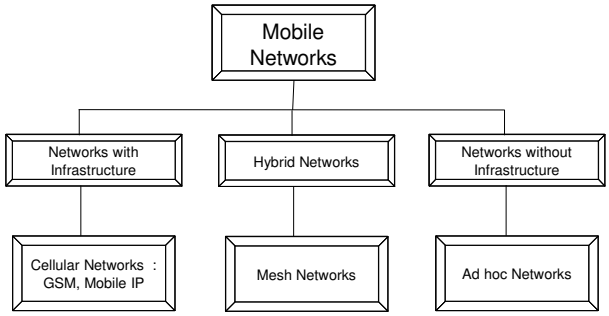
Course Outlinse

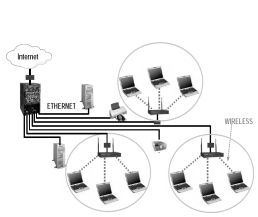
- Introduction
- Wireless Mesh Networks
  - Definitions, Applications and Standardization Activities
  - Wifi Mesh networks and 802.11s standard
  - Current deployments
  - France Telecom Activities

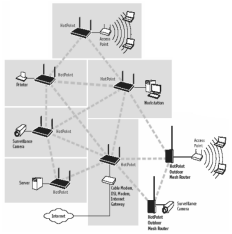
Introduction



Wireless Mesh Networks

WiFi Paradox and WiFi Mesh network benefits

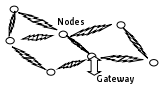




- WiFi Networks paradox => Lots of wires
  - network wires
  - power supply wires
- Mesh Networks => Only power supply unit wires
  - Easier deployments and new opportunities!

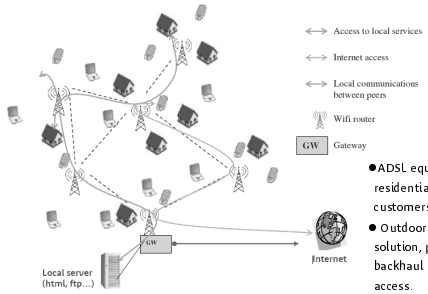
Wireless Mesh Networks

- Basic Definition
  - A mesh network is made up of a grid of nodes which collaborate to exchange information with their neighbours through adapted interfaces. Usually, mesh networks are based on wireless links, with the strong advantage to cover areas where no wired connection to backhaul network is available.



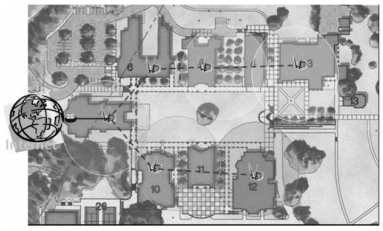
- The embedded dynamic multi-hop routing function enables the key features:
  - Self-Configuring, Self-Healing

Wireless Mesh Applications and Scenarios
Residential – Small Enterprise



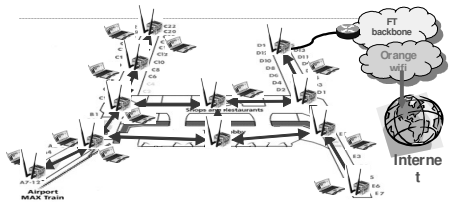
- ADSL equivalent offers for residential/small enterprise customers who are deprived of.
- Outdoor mesh networking solution, possibly 802.11g in backhaul and 802.11b/g in access.

Wireless Mesh Applications and Scenarios
Campus/Corporate Scenarios (Community)



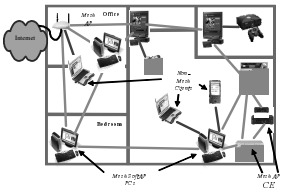
➔ Efficiently cover campus or corporate area indoor/outdoor at once and thus provide for wireless P2P, internet and intranet access everywhere from these areas.

Wireless Mesh Applications and Scenarios
Hotspot Extensions



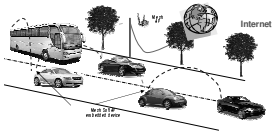
➔ Mesh networks provide a great opportunity to easily extend the radio coverage of operator hot-spots.

Wireless Mesh Applications and Scenarios
Other Application Cases in Medium Term

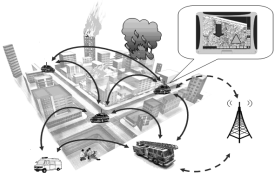


➔ Domestic Networks (maison numérique)

➔ Car-to-Car Networks associated with a fixed infrastructure.



Wireless Mesh Applications and Scenarios
Other Application Cases



➔ Emergency operations

Business and Key Technical Challenges

Mesh technology	Advantages	Limitations
Technical Challenges	⊙ *Ethernet cabling constraints removed (Number of wired attachment points strongly reduced)* ⊙ *Network scalability made easier* ⊙ *Network robustness improved (Multiple redundant communications paths throughout the network)* ⊙ *Urgent manual interventions less critical and management task simplified (centralized)*	⊙ *Available bandwidth still limited on backhaul links (few Mbps)* ⊙ *Dimensioning task more complex (shared access media)* ⊙ *Non standardized technology (Coming next)* ⊙ *No inter-operability between solutions*
Business challenges	⊙ *low cost and easy-to-deploy solution* ⊙ *New opportunity of deployment and coverage in outdoor cases compared with classical HotSpot solution (e.g.residential & metropolitan areas)* ⊙ *great interest for temporary events since well suitable (easy to deploy and self-organized network)*	⊙ *Capex cost of mesh greater than capex cost of classical Wi-Fi infrastructure* ⊙ *Non standardized technology*

Standardization Activities

➔ IEEE: dedicated TGs

IEEE Standard/ Amendment	Function	Ratification Date	Frequency band
802.15.5	Determining necessary mechanisms enabling WMNs in WPANs PHY and MAC layers	2010	2.4 GHz ISM-band
802.11s	Extending 802.11 WLAN architecture to enable mesh functionalities (Wifi Mesh networks)	2009	2.4, 5 GHz
802.16j	Mesh mode in Mobile Multihop Relay (MMR)	2009	TBD
802.16e	Amendment on 802.16a supporting stations moving at vehicular speeds	Feb. 2006	2-6 GHz

Wifi Mesh Networks and IEEE 802.11s

Wifi Mesh technology

➔ Natural development of Wi-Fi networks

➔ Designed to deploy WLANs in areas where usual Wi-Fi hotspot solutions are too expensive because of cabling

Wifi Mesh technology

➔ Three generations of equipments are available on the market

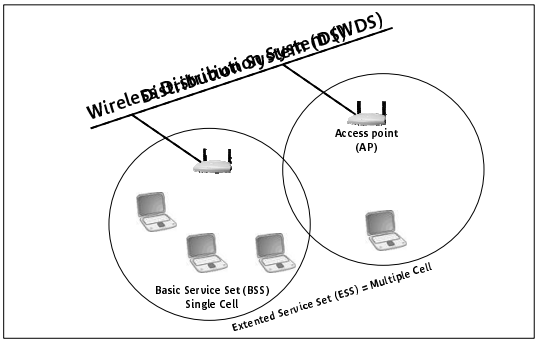
Mesh networks	1st generation network	2nd generation network	3rd generation network
Radio module per node	1 radio 802.11b/g	2 radios 802.11b/g & 802.11a	3 or more radios 802.11b/g & 802.11a
Node modularity	Fixed configuration	Fixed configuration	Modular nodes
Large scale deployments	Very limited	Limited	Possible
Delay per hop	High	Medium – high	Low
Throughput per hop	Very low	Low	High
Support of Real-Time applications	Very limited	Limited	Possible
Vendors	Tropos, Motorola, Cisco	Nortel, Cisco, Aruba, Colubris, Proxim, Belair, Motorola, Tropos, Sagem,	Belair, Strix Systems, Mesh Dynamics, Sagem, Motorola

802.11s Standard

➔ Scope of TGs
- Main Idea
- Purpose of Project
- Future Amendment Overview
- Main Suppliers
- Terms And Definitions

➔ Details on functional categories relevant to 802.11s

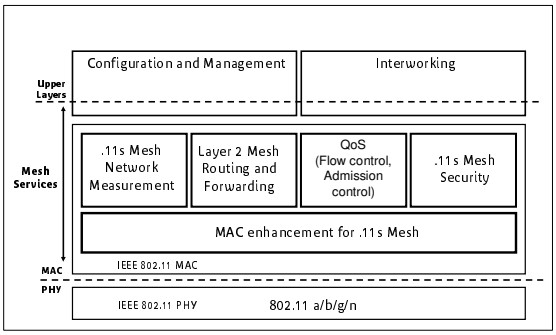
802.11s Main Idea



802.11s Purpose of Project

- **Provide a mesh network standard with the following features**
  - Mechanisms at Layer 2 or 2.5
  - Protocol for auto-configuring paths between Mesh Points
    - multi-hop topologies
    - Automatic topology learning
    - Self-Healing
    - Self-configuring and routing (Broadcast/Multicast/Unicast Mac delivery)
  - Radio
    - Radio awareness
    - Multiple-radios support per Mesh Points
  - Security : Based on 802.11i or an Extension
  - QoS : Based on an extension of 802.11e to enable flow control over multi-hop paths
  - Ensure support for interfacing with higher layers => **3rd generation**
  - Enable interoperability, extensibility
  - Up to 32 Mesh Points
- **Project completion date : 2009**

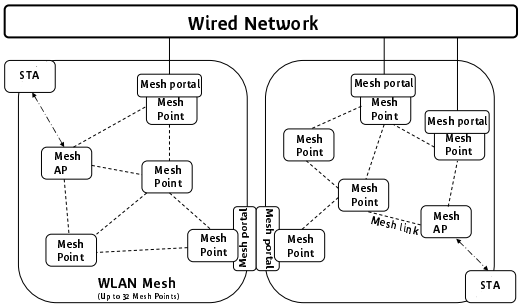
Futur 802.11s Amendment Overview



802.11s Main actors

- **Intel Corporation**
- **Nortels Networks**
- **CISCO**
- Motorola (Mesh Networks)
- U.S Naval Research Laboratory
- France Telecom R&D
- **Thomson**
- Samsung
- **University of Aachen (Germany)**
- Siemens
- BelAir Networks
- Sony
- Fujistu
- Tropos Networks
- **NTT DoCoMo**

Terms And Definitions (1/2)



Terms And Definitions (2/2)

- **WLAN Mesh**
  - IEEE 802.11-based WDS which is part of a DS, consisting of a set of two or more Mesh Points interconnected via IEEE 802.11 links and communicating via the WLAN Mesh Services
- **WLAN Mesh Services**
  - Set of services provided by the WLAN Mesh that support the control, management, and operation of the WLAN Mesh
- **Mesh Point**
  - IEEE 802.11 conformant MAC and PHY
  - Within WLAN Mesh and supports WLAN Mesh Services
- **Mesh AP**
  - Mesh Point that is also an Access Point
- **Mesh Portal**
  - A point at which MSDUs (MAC Service Data Unit) exit and enter a WLAN Mesh to and from other parts of a DS or to and from a non-802.11 network

Deployement characteristics Table

Usage Model	# Mesh Points/APs	Aera Size (m2)	Environment	Mesh Point/APs Join/Exit frequency	Mesh Points/Aps Mobility	# STAs
Residential	8 (small)	100-400	Indoor	Low	Low	6 (small)
Office	Large (32-100)	1000-8000	Mostly Indoor	Low	Mostly Fixed	Large (50-300)
Campus Community Public Access	Large (50-100) 32 per 11s mesh	>= 1000	Mostly Outdoor	Low	Mostly Fixed	Large (20-1000)
Public Safety	Large	>= 250	Mostly outdoor	High	Fixed and Mobile	30-250
Military	Large	>= 250	Mostly Outdoor	High	Mostly Mobile	30-250

802.11s Outline

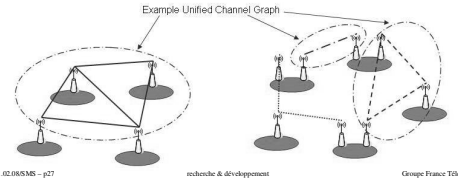
- Scope of TGs
- Details on functional categories relevant to 802.11s
  - Topology Formation
  - Measurement and Routing
  - Medium Access Coordination
  - Security
  - Interworking
  - Mobility

Topology Formation

- Mesh Points (MPs) that are not yet members of the mesh must first perform neighbor discovery
- The node scans neighboring nodes to find at least one matching profile (mesh ID, routing protocol type, etc.) . The scanning can be:
  - **Passive scanning**: MPs listen for beacon frames (mesh profile is in the beacon),
  - **Active scanning**: MPs exchange probe request / probe response frames (mesh profile is in the probe response).
- After discovering a mesh network, the new mesh point starts mutual authentication and establishes a secure peer links with neighbors in the mesh, since it supports the mesh profile.

Topology Formation

- Each Mesh Point may have one or more logical radio interface
- A Unified Channel Graph (UCG) is a set of nodes that are interconnected on the same channel within a mesh network.



Network Measurement and Routing

- Routing protocol consists in finding on optimal route in layer-2 (based on MAC addresses)
- Based on the results of MANET Working Group.
- Two protocols are considered
  - **HWMP** (Hybrid Wireless Mesh Protocol): this is the default routing protocol and therefore must be implemented on all nodes. It is the combination of 2 protocols: RM-AODV and Tree Based Routing protocol.
    - *–RM-AODV (Radio Metric Ad hoc On-Demand Vector) is based on AODV. Used for a P2P Mesh Routing.*
    - *–Tree Based Routing is a proactive protocol used to build and maintain a distance vector routing tree starting from the MPP.*
  - **RA-OLSR** (Radio-Aware Optimized Link State Routing): This is an optional routing protocol. It is suitable for low mobility. It is based on OLSR proactive protocol developed by MANET. Group extended with radio aware metric used for decisions.

Network Measurement and Routing

- For the moment, most of the main mesh manufacturers (Nortel, Cisco, StrixSystems, Mesh Dynamics, Columbris, Proxim, Motorola, etc.) have developed their own routing protocol by adapting for wireless existing common protocols like OSPF, Spanning Tree.

Network Measurement and Routing

- Mesh routing protocols use **mesh network measurements** in order to determine the best route. Measurements used are:
  - Mesh link quality
    - *–AirTime (default) : quantité de ressource radio consommée lors de la transmission d'une trame sur un lien.*
    - *–Delay*
    - *–Jitter*
    - *–Throughput*
    - *–Data rate encoding*
    - *–Noise*
    - *–SNR (Signal Noise Ratio)*
  - Mesh Path Quality
    - *– Best path among possible paths (depending on above criteria)*
  - Other statistics defined by 802.11k (radio ressources measurments) can and should be used for mesh routing

Medium Access

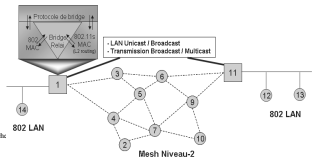
- **MAC QoS enhancement introduced by 802.11e (EDCA) is used as baseline by 802.11s**
  - Mandatory MAC Functions
  - EDCA proposes up to 4 access categories:
    - Voice (Highest priority)
    - Video
    - Best effort
    - Background (lowest priority)
- **Optional MAC Enhancements**
  - Mesh Deterministic Access (MDA)
  - Reservation- based deterministic mechanism
  - Common Channel Framework (CCF)
  - Multi- channel operation mechanism
  - Intra- mesh Congestion Control
  - Power Management

Security

- **Security in 802.11s WiFi Mesh networks is based/built on top of security mechanisms proposed by 802.11i standard.**
- **802.11i allows:**
  - Distributed authentication (or personal WPA): authentication occurs between two nodes using Pre-Shared Key (PSK),
  - Centralized authentication (or WPA Enterprise) authentication is managed by an authentication server (802.1x, RADIUS generally).
- **The specific functionalities developed by 802.11s Task Group are:**
  - Mutual authentication between mesh nodes,
  - Protection of mesh management and control messages exchanged between Mesh nodes (e.g. routing and topology information).

Interworking

- **Support for interfacing a WLAN Mesh with other IEEE 802 LANs using 802.1D (Bridge)**
- **Support for efficient utilization of multiple Mesh Portals in a single WLAN Mesh**
- **To deliver packet and if the destination is**
  - Inside the mesh network, the MP uses layer-2 mesh path discovery/forwarding.
  - Outside the mesh network, the MP identifies the target portal, and delivers packets. If no target portal can be identified, the packets are delivered to all mesh portals.



Mobility

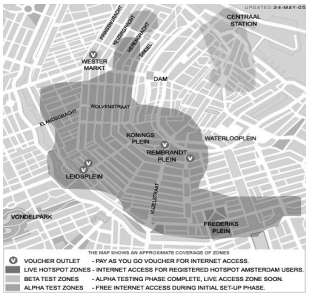
- **No specific mobility mechanism is anticipated in the IEEE 802.11s group.**

What is the actual situation?

- **IEEE 802.11s not yet standardized (scheduled for 2009)**
  - Different constructor equipments can't communicate together
  - Equipments are still expensive

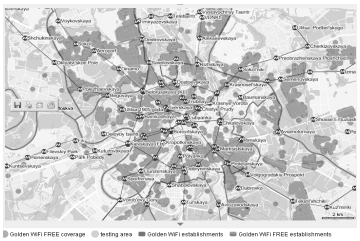
Current deployments

Deployments
Amsterdam



- More than 100 AP deployed
- Mesh solution
- Offer seamless roaming
- Hotspot Amsterdam Offer (Online Payment)

Deployments
Moscow (Golden Telecom avec Nortel Networks)



Coverage
- 6,700 AP deployed
- 800,000 houses covered

Technology
- 802.11b/g, WiFi Mesh

Services & Fares
- ~2Mbps broadband Internet access (VoIP, Internet access, localization based services)
- Existence of free access areas

Deployments
San Francisco

- 78 square km "cloud"
- EarthLink is expected to charge about US$20 a month for ad-free connections running at around 1Mbps, while Google essentially pays Earthlink for network access and provides a free access with a throughput up to 300Kbps.
- City infrastructure: 1900 lamp posts, schools, towers and roof-tops.

Contact

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