Wireless Mesh Networks

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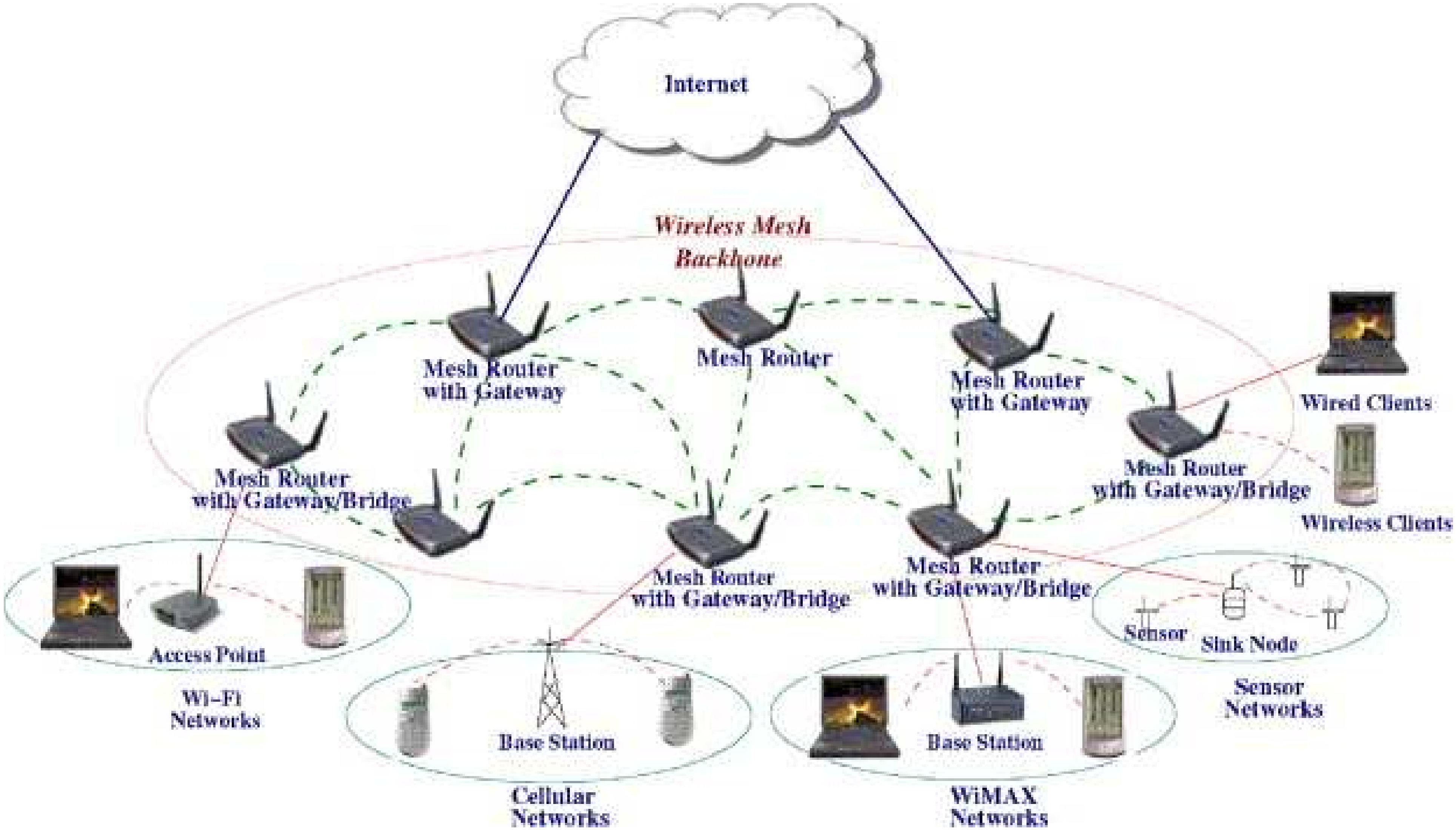
Part of this material (including some pictures) features and are freely reproduced from:
"Ian F.Akyildiz, Xudong Wang,Weilin Wang, 'Wireless mesh networks: a survey', Computer Networks 47 (2005), Elsevier"

Thanks also to Gianni Costanzi for checks and providing figures

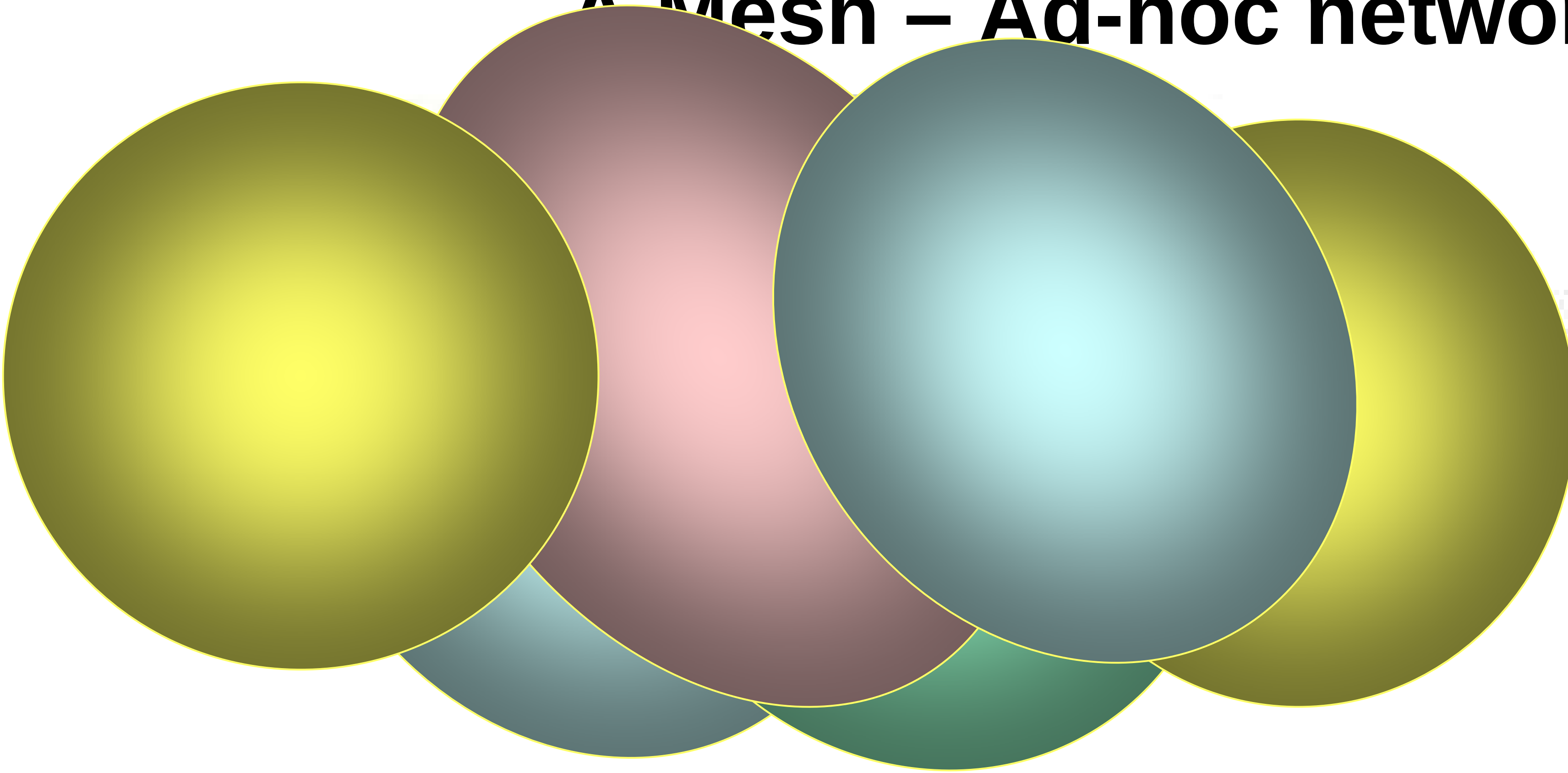
Ad-Hoc and WMN

- Ad-Hoc network
  - non permanent
  - general purpose or specific (sensors)
  - single or multi-hop, normally mobile
  - may require routing (see AODV and OLSR in the following)
- Wireless Mesh Networks (WMN)
  - more structured than Ad-Hoc
  - may be hierarchical
  - semi-permanent, some nodes are fixed
  - requires routing

WMN: a general view



A Mesh – Ad-hoc network



- Ad-Hoc can be meshed
  - non single broadcast channel
  - multi-hop require routing

Hierarchical meshes

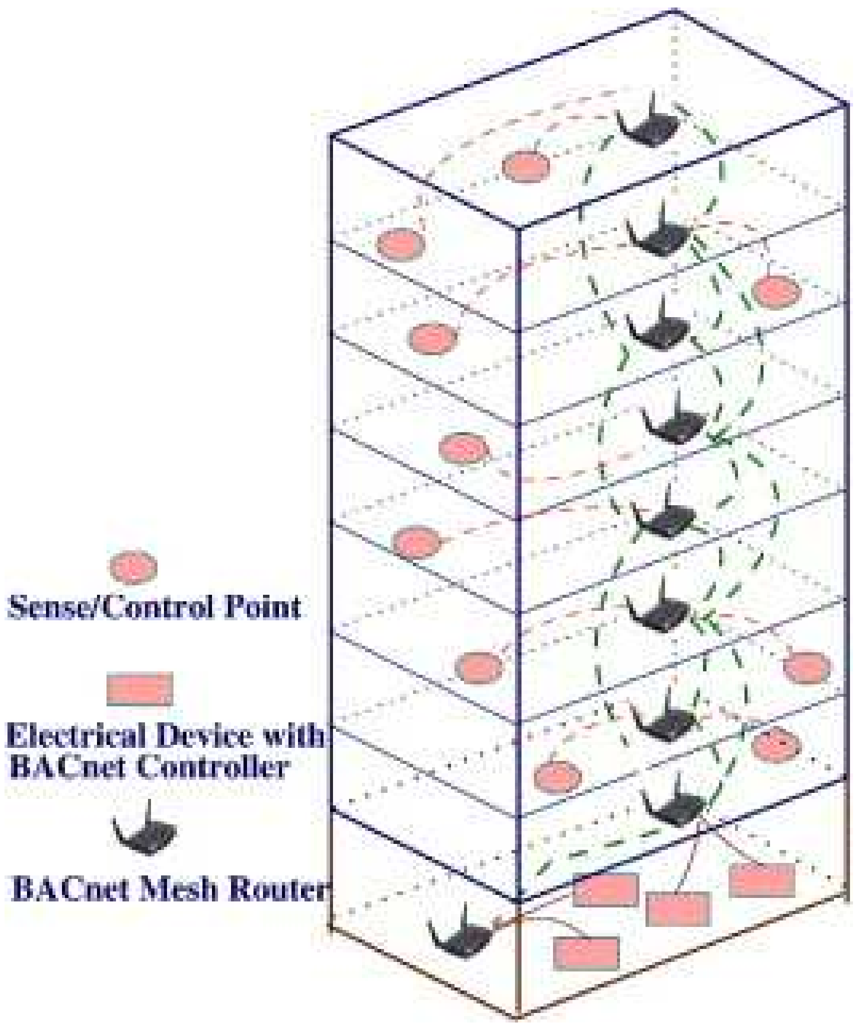
Hierarchical meshes

- Capacity of the backbone
- Routing strategies
  - Gateway selection
    - client level
    - backbone level
- Backbone of fixed nodes
  - multi-km links -> easy and cheap coverage
  - replace wireless “closed” backbones
  - Nomadic access vs. static access

Domestic Mesh

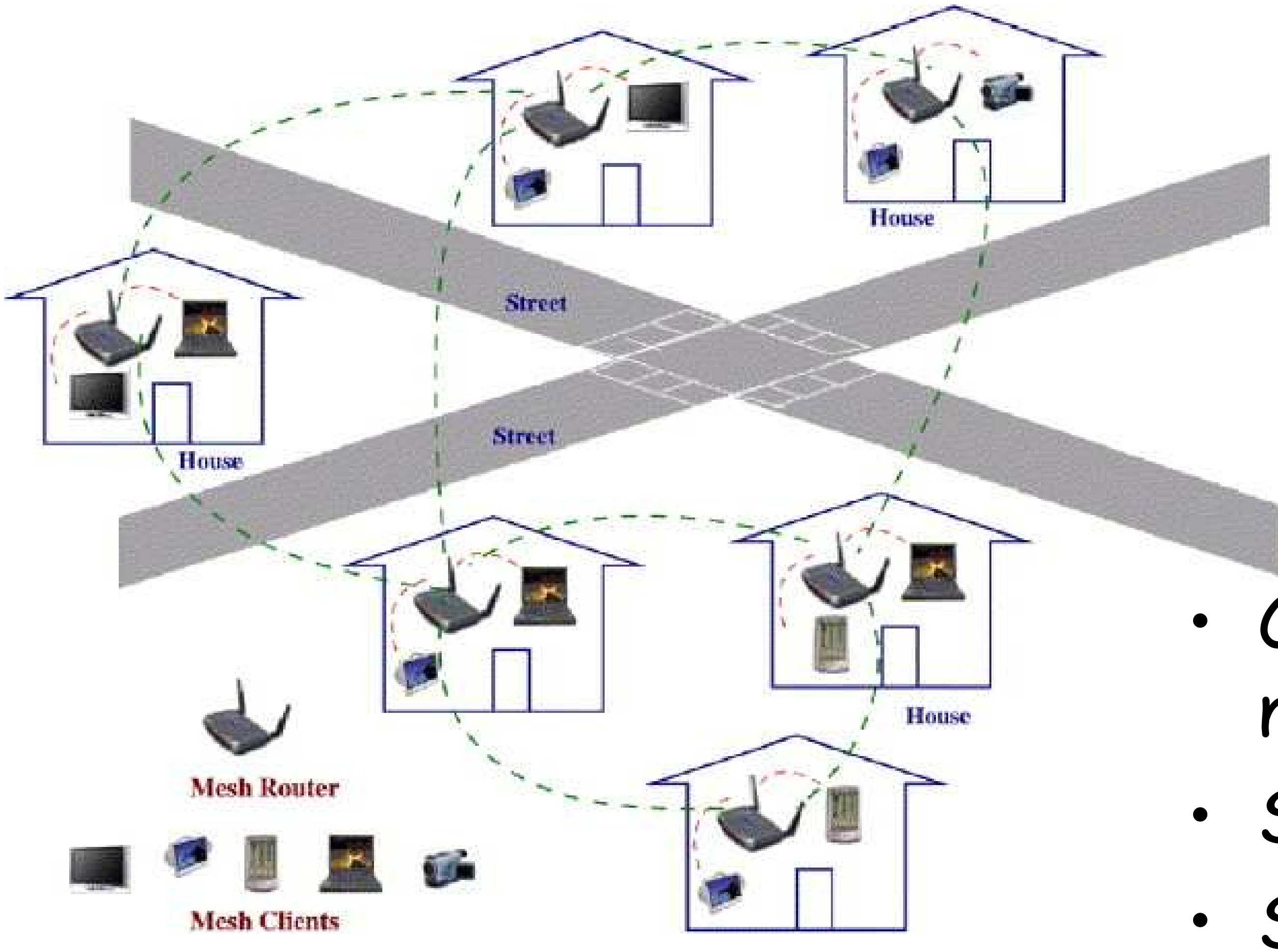
- Simplify home cabling
- Can support anti-intrusion
- Distribute e.g. IPTV

Building automation



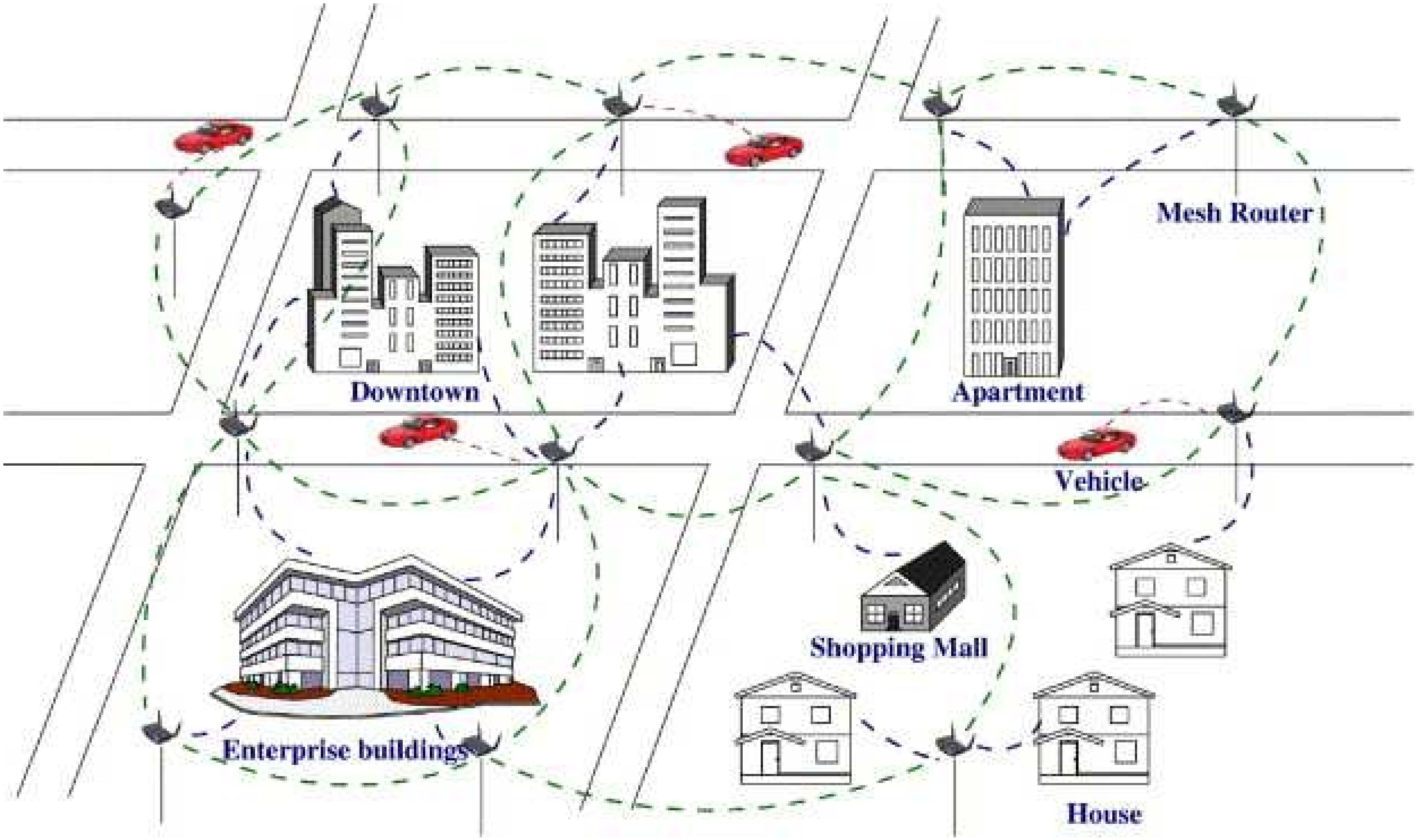
- Simplify cabling
- Allow central control
  - vs. pure sensor/actuator networking where information is not propagated
- Simple, static routing
- Reliability concerns

Multi-home meshes



- Community networks
- Social networks
- SOHO support
- Nomadic access

Vehicular-metropolitan networks

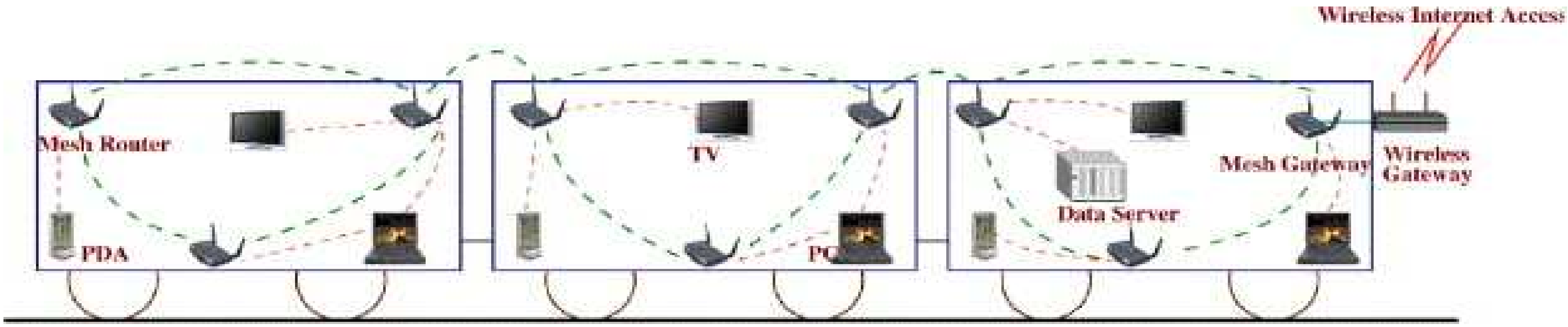


Vehicular-metropolitan networks

- Mainly infrastructure-to-vehicle
  - cooperative driving is a different (though related) story
- Traffic control & congestion management
  - A22 is “selling” as the “future” 73 messaging panels on close to 300 km …
- Turism, advertisement, local information
- Nomadic communication with pedestrians too

- In U.S. some commercial experiments are already available

Train & Planes networks

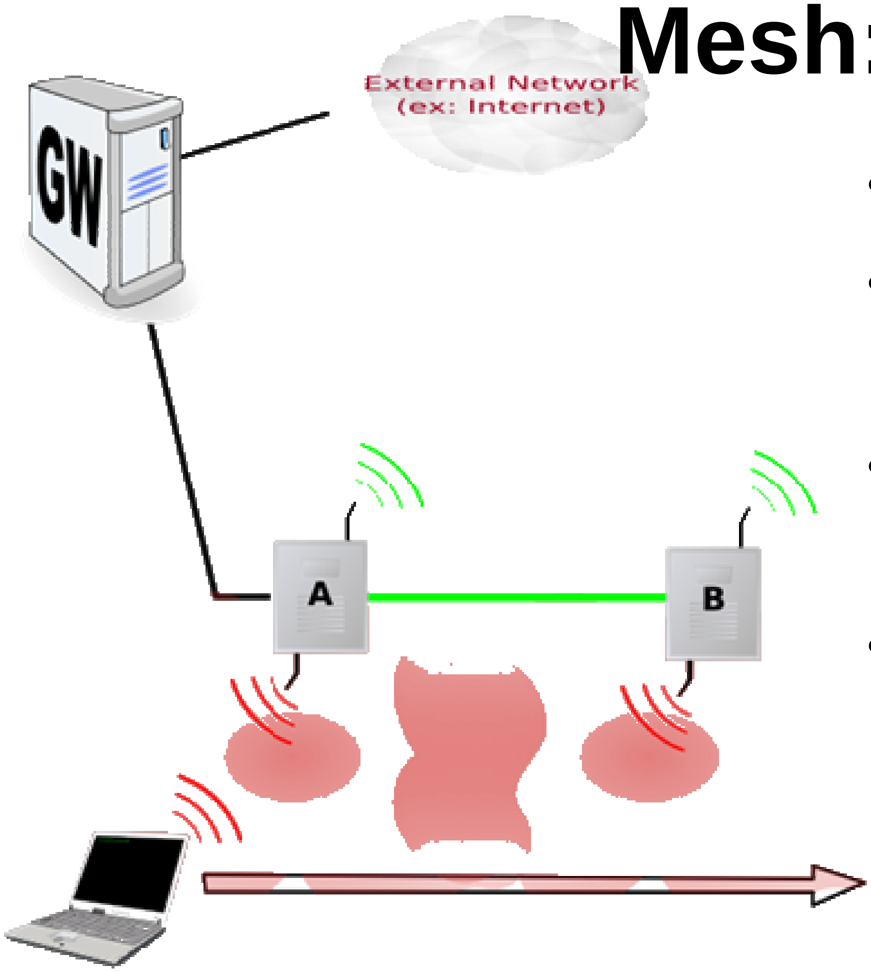


- Cellular networks?
  - capacity problems in “dense” environments
  - cannot “reach” planes
  - problems with very high speed
- Collect the traffic locally then interconnect from a single – non energy constrained point

Mesh project & sites

- Community Networks & around
  - Seattle Wireless (http://www.seattlewireless.net/)
  - Roofnet at MIT (http://pdos.csail.mit.edu/roofnet/)
  - TFA at Rice (http://tfa.rice.edu)
  - Tuscolo Mesh (http://tuscolomesh.ninux.org/joomla)
  - Georgia Tech (http://www.ece.gatech.edu/research/labs/bwn/mesh/index.html)
  - ...
  - Pergine Valsugana
  - ...
  - Trentino Networks

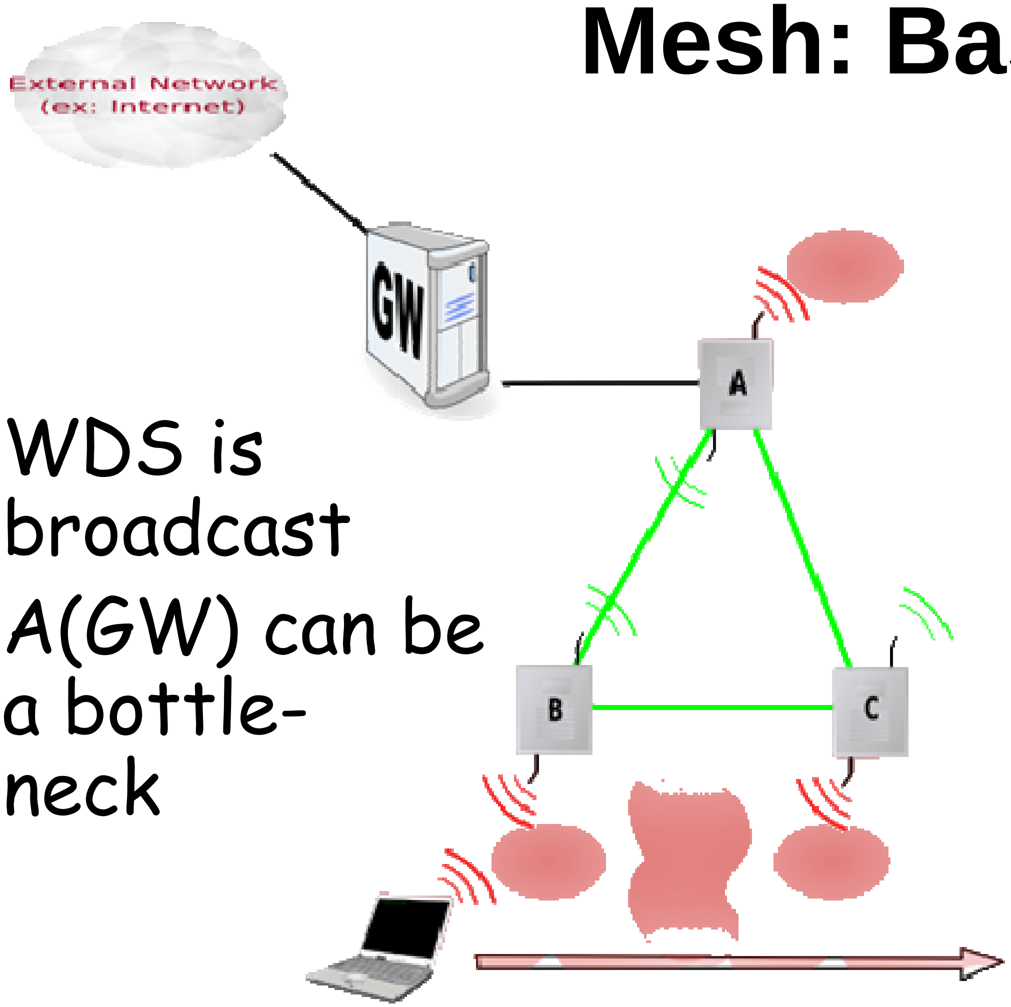
Mesh: Basic scenarios (1)



- Extended WLAN access
- Simple configuration
  - no routing
- Simple 802.11 handover support
- Double radio guarantees good performance

- Single radio creates resource conflicts
  - 3 BSS on the same channel
  - suitable for low-cost low-performance

Mesh: Basic scenarios (2)

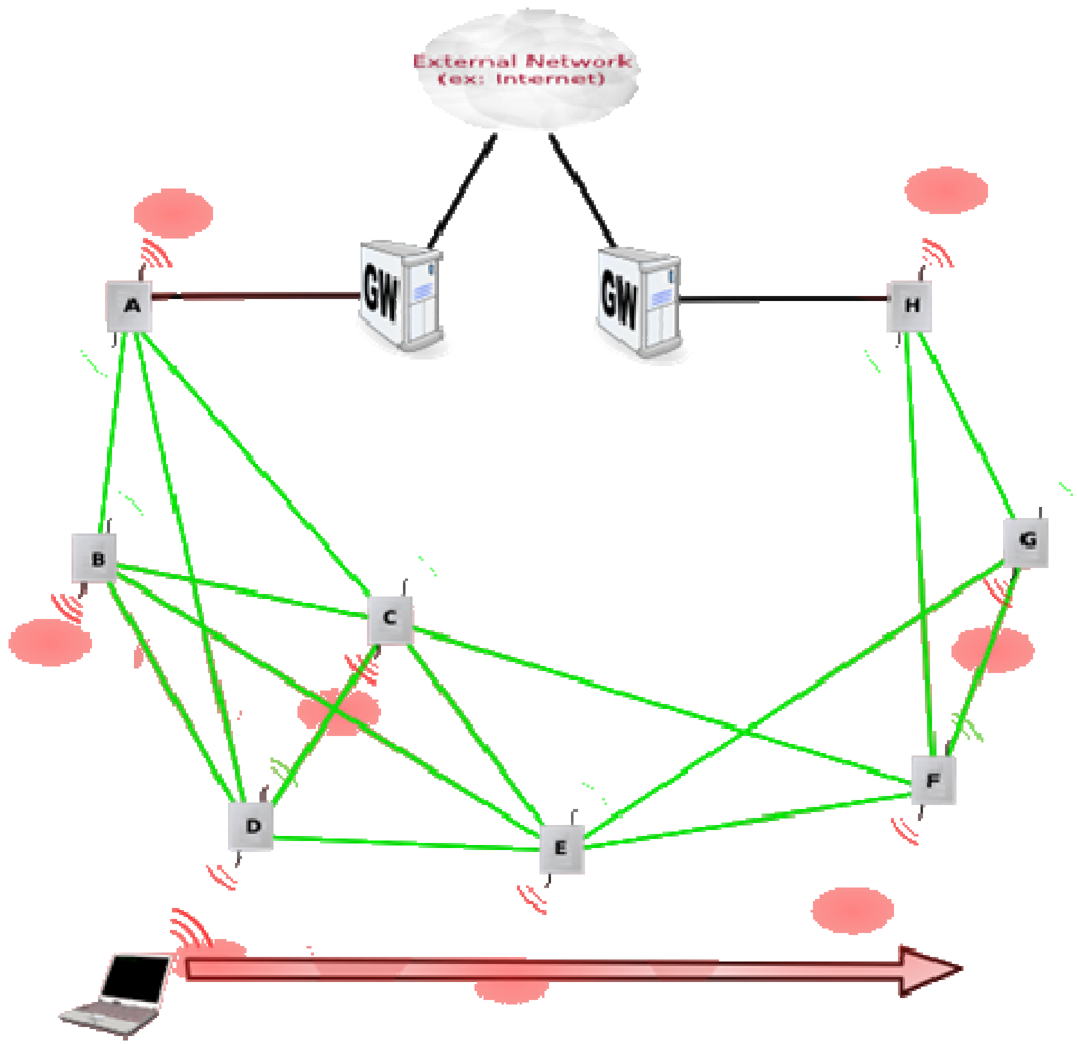


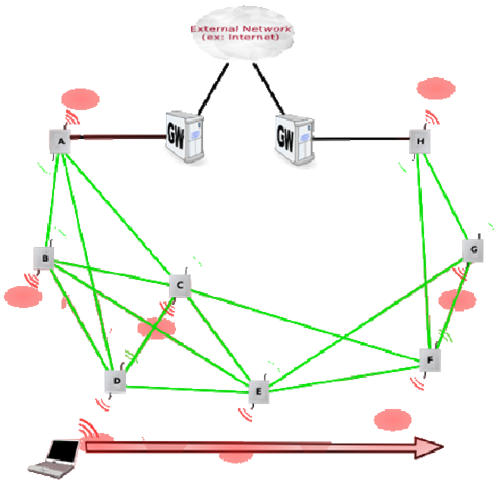
- WDS is broadcast
- A(GW) can be a bottle-neck

- Extended WLAN access
- Routing required
- Simple 802.11 handover support
- Double radio guarantees good performance

- Single radio creates serious resource conflicts
  - n+1 BSS on the same channel

Mesh: Basic scenarios (3)



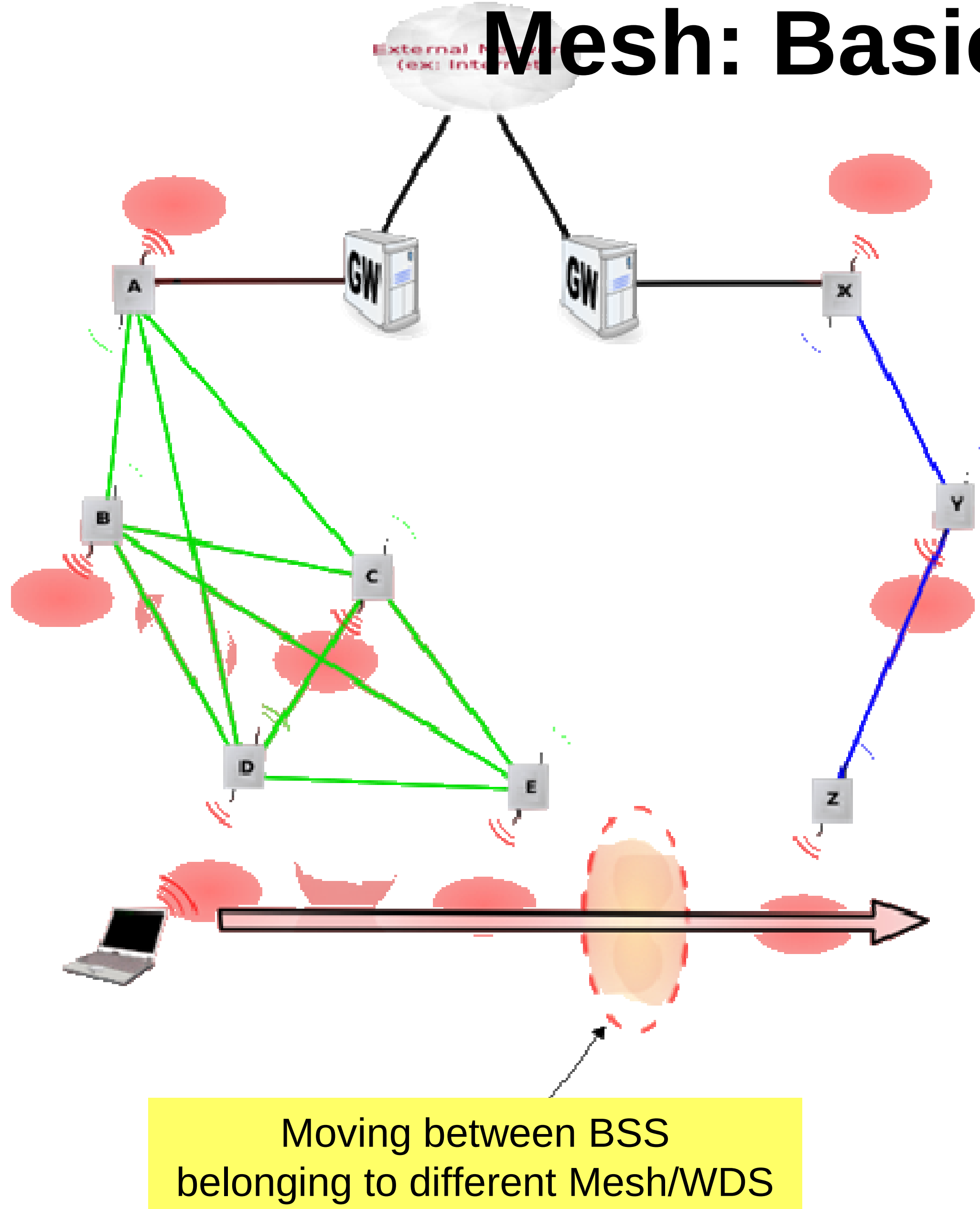


Mesh: Basic scenarios (3)

- Extended WLAN access
- Basic infrastructuring
- Single radio operation very difficult

- Multiple external gateways
  - sophisticated, flow-based routing
- Non standard handover support
  - flow based routing requires exporting the context
  - address management require coordination
- WDS may be multi-hop
  - How many channels?
- Point-to-point and broadcast channels in WDS

Mesh: Basic scenarios (3)



- Address management (DHCP) is a problem
- Flow-based routing may be impossible
- Joining/splitting of partitions is an open issue

Mesh – Ad-Hoc: AODV

Ad-hoc On-demand Distance Vector routing – rfc3561

- DV (see RIP) protocol for next-hop based routing
- On-Demand: maintains routes only for nodes that are communicating
- Must build routes when requested
- Route Request (RREQ) are flooded through the network
- Nodes set-up reverse path pointers to the source
  - *AODV assumes symmetric links*

Mesh – Ad-Hoc: AODV

- The intended receiver sends back a Route Reply (RR)
- RR follow the reverse path set-up by intermediate nodes (unicast) establishing a shortest path route memorized by intermediate nodes
- Paths expire if not used
  - protocol & transmission overhead
  - guarantee of stability in dynamic, non reliable networks
- Usual DV problems
  - count to infinity, slow convergence, ...

Mesh – Ad-Hoc: AODV

- Next-hop based (other proposals are based on source routing)
- “Flat” protocol: all nodes are equal
- Can manage only one route per s-d pair
  - can be inefficient in presence of highly variable link quality and persistence
- Good for sporadic communications
- Bad for high mobility
  - slow convergence
  - difficulty in understanding topology changes.

Mesh – Ad-Hoc: AOMDV

Ad-Hoc On-demand Multipath Distance Vector Routing in Ad Hoc Networks

- An extension to AODV
- AOMDV computes multiple loop-free and link-disjoint paths
- Using "Advertised Hop-count" guarantees Loop-freedom
  - A variable, which is defined as the maximum hop count for all the paths. A node only accepts an alternate path to the destination if it has a lower hop count than the advertised hop count for that destination
- Link-disjointness of multiple paths is achieved by using a particular property of flooding
- Performance comparison of AOMDV with AODV shows that
  - AOMDV improves the end-to-end delay, often more than a factor of two
  - AOMDV reduces routing overheads by about 20%

Mesh – Ad-Hoc: OLSR

Optimized Link-State Routing Protocol (rfc3626)

- Proactive, link-state routing protocol
- Based on the notion of MultiPoint Relay (MPR)
- Three main components:
  - Neighbor Sensing mechanism
  - MPR Flooding mechanism
  - topology Discovery (diffusion) mechanism.

- Auxilary features of OLSR:
  - network association - connecting OLSR to other networks

Mesh – Ad-Hoc: OLSR

Basic neighbor sensing:

- periodic exchange of HELLO messages;
- HELLO messages list neighbors + "neighbor quality"
  - HEARD - link may be asymmetric
  - SYM - link is confirmed to be symmetric
  - MPR - link is confirmed to be symmetric AND neighbor selected as MPR
- Providing:
  - topology information up to two hops
  - MPR selector information notification

Mesh – Ad-Hoc: OLSR

- Each node selects from among its neighbors an MPR set such that
  - an emitted flooding message, relayed by the MPR nodes, can be received by all nodes in the 2-hop neighborhood

- Goals:
  - reduce flooding overhead (select minimal sets)
  - provide optimal flooding distances

Mesh – Ad-Hoc: OLSR

- Exchanges topology information with other nodes of the network regularly
- MPRs announce their status periodically in control messages.
- In route calculation, the MPRs are used to form the route from a given node to any destination in the network
- Uses MPRs to facilitate efficient flooding of control messages

Mesh Networks: 802.11s

- Working group to deliver a standard for 802.11(& around) base Mesh Networks
  - Interactions with 802.11p dedicated to vehicular networks

- Tries to define a framework to support a Mesh network as a standard extended WLAN with routing that goes beyond the standard minimum spanning tree of 802.1 interconnection

Device Classes in 802.11s

- Mesh Point (MP)
  - a point able to relay messages
- Mesh AP (MAP)
  - a MP able to provide services to STAs
- Mesh Portal (MPP)
  - a MAP connected to a wired LAN
  - normally called a gateway and assumed to access the internet

Routing in 802.11s

- Hybrid Wireless Mesh Protocol (HWMP) - Mandatory
  - AODV derived link-state protocol
  - Based on trees for proaction and efficiency
  - Add on-demand features (like AODV)
- Radio Aware OLSR (RA-OLSR) – Optional
  - Radio aware metrics added to MPRs in OLSR
  - optional fish-eye routing capabilities
  - association and discovery protocols for topology discovery and buildup