Communication in Distributed Systems

Kommunikation in verteilten Systemen

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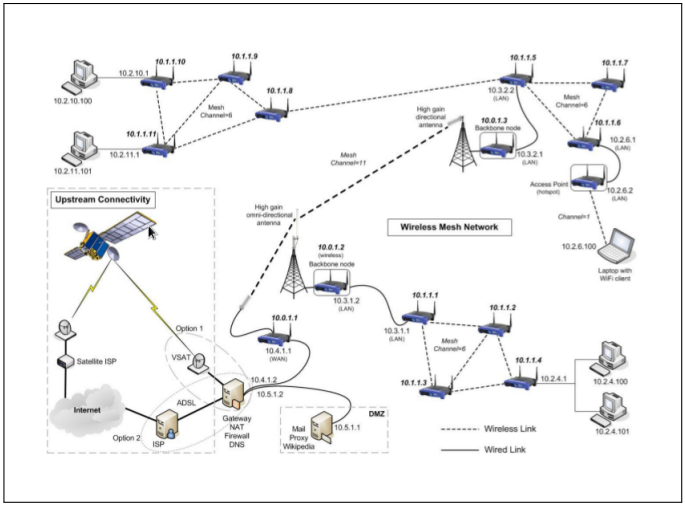
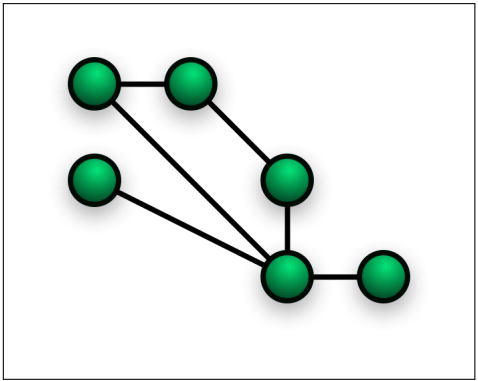
Wireless Mesh Networks



- **Wireless** → radio links
- **Mesh** → Multiple paths between sender and receiver
- **Network** → Routers and repeaters forward traffic over multiple hops from sender to receiver

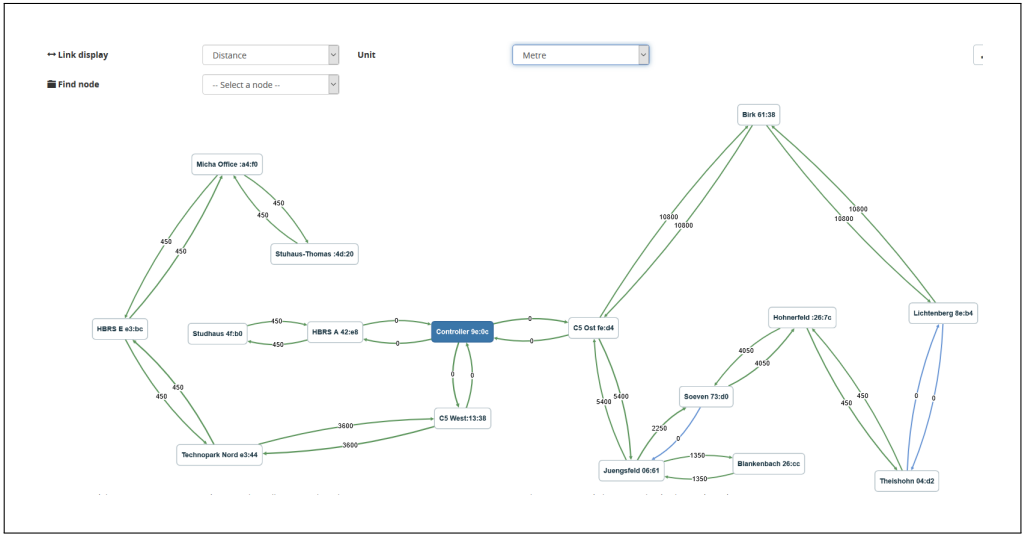
Wireless Mesh Networks – Topologies



- A **mesh network** is a topology in which each node relays data for the network
- All mesh nodes cooperate in the distribution of data in the network
- In a **full mesh**, every node is connected with every other node sender to receiver

Microsoft Research: Mesh Networking (copied from youtube.com) (4:06)

Wireless Mesh Networks – Theishohnbed

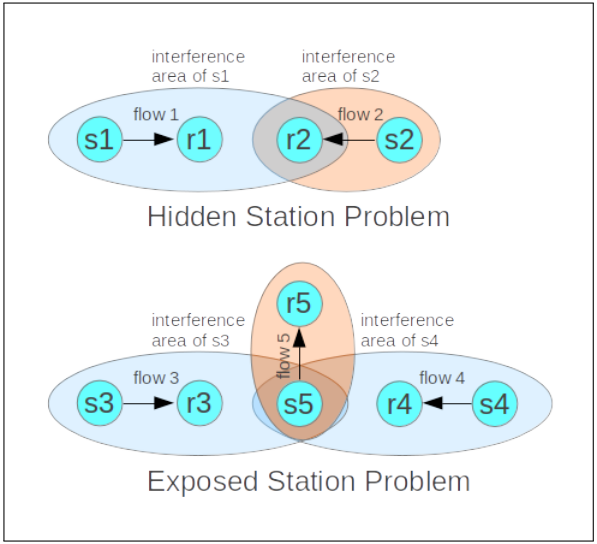


Wireless Mesh Networks – The Good and the Bad

- based on IEEE 802.11
- huge distances (>100 km)
- flexible
- cost efficient

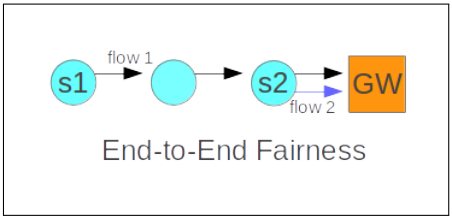
- all traffic passes the IGW
- network self-interference (neighbor nodes)
- ISM-band is free-to-use by everyone
- fair access is a challenge

Wireless Mesh Networks – Fairness



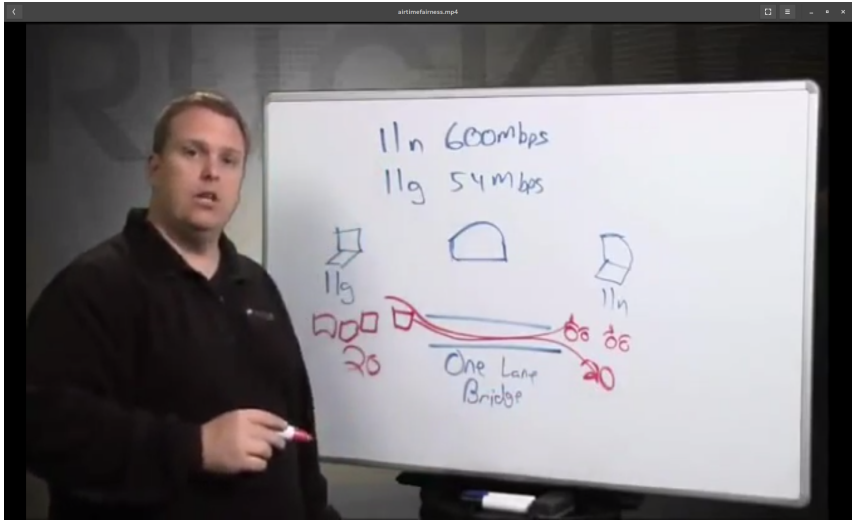
- Wireless channel is the **critical ressource**
- Should be equally available to all stations
- **Unfairness** derives from
  - Hidden Station Problem
  - Exposed Station Problem
  - 802.11 MAC back-off timer

Wireless Mesh Networks – End-to-End Fairness



Multihop transmissions are disadvantaged

- multiple spectrum allocations
- accumulation of transmission errors
- TCP back-off



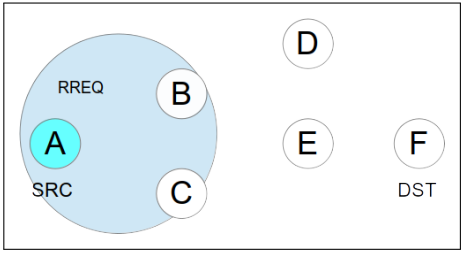
RuckusAU: Air Time Fairness (copied from youtube.com) (5:20)

Ad-hoc On-demand Distance Vector Routing Protocol (AODV)

- Routing protocol for ad-hoc networks
- Mobile or static
- Re-active distance-vector routing
  - Discovers routes when needed
  - Routes are maintained as long as necessary

- SRC broadcasts RREQ
- RREQ forwarded by all nodes
  - intermediate nodes install reverse route
- DST sends RREP back to SRC (unicast)
  - intermediate nodes install forwarding route
- Intermediate nodes may create RREP

AODV RREQ


RREQ
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SRC
B
C
D
E
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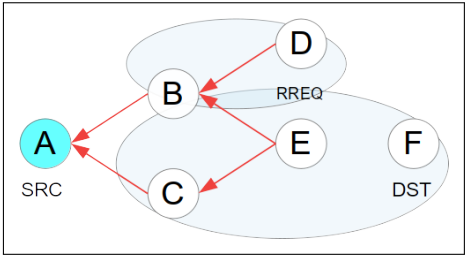
DST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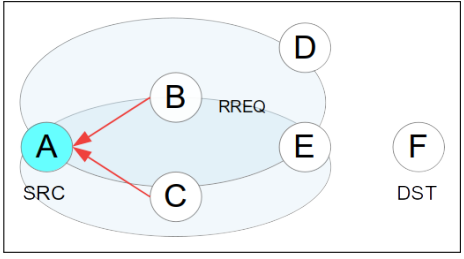
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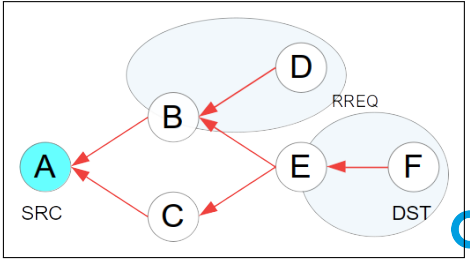
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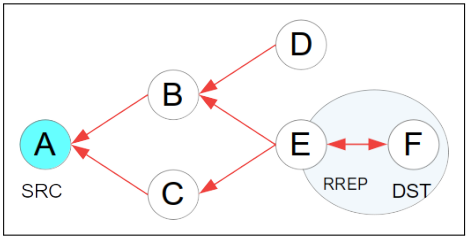
AODV RREP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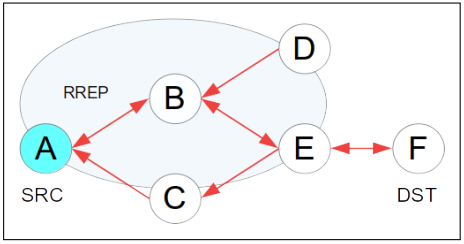
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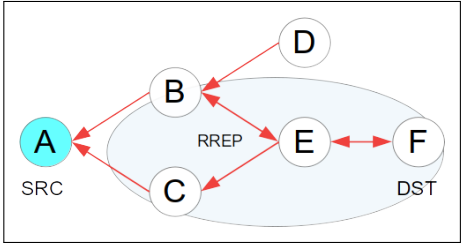
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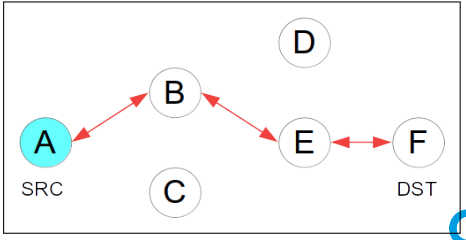
D
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SRC
C
DST

Optimized Link State Routing Protocol (OLSR)

- Routing protocol for ad-hoc networks
- Mobile or static
- Pro-active link-state routing
- Select *Multipoint Relays* (MPR) to reach all 2-hop-neighbours
- Forwarding path is not shared among all nodes (MPRs only)
- Doesn't bother with reliability; MPRs simply flood topology data often enough

HELLO Messages

- Find neighbors and 2-hop-neighbours

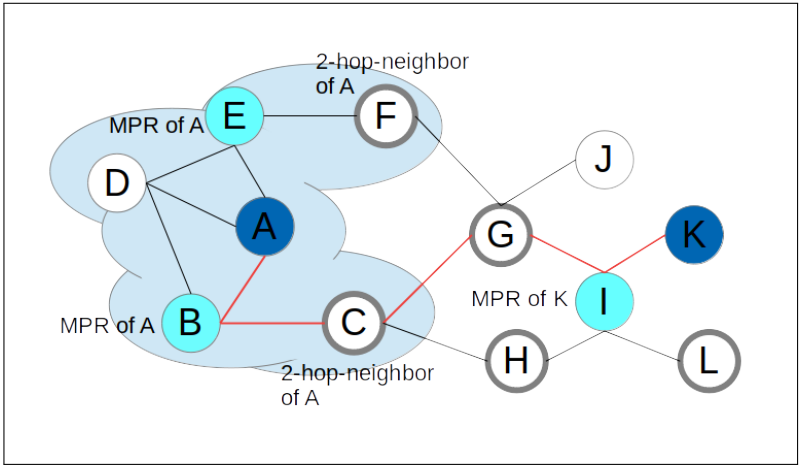
TC: Traffic control Messages

- Generated and forwarded by MPRs
- Include *MPR Selectors*
- Broadcasted periodically

HNA Messages

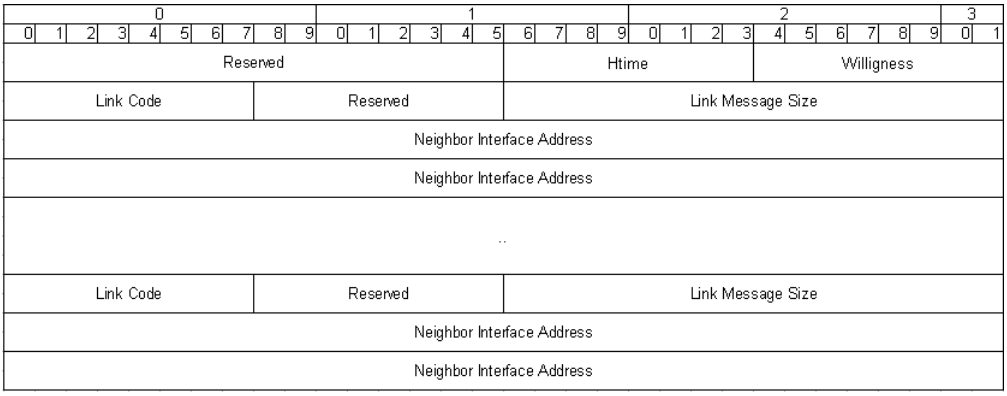
- Announce host-network-associations

OLSR MPR Selection

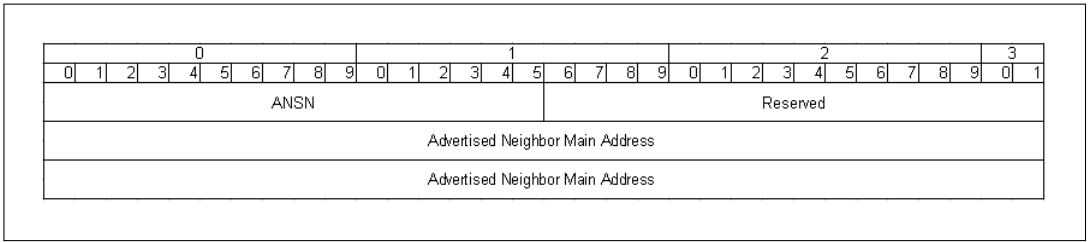


- A and K select E,B,I as MPRs (HELLO)
- E,B,I exchange TCs
- Path selection based on TCs

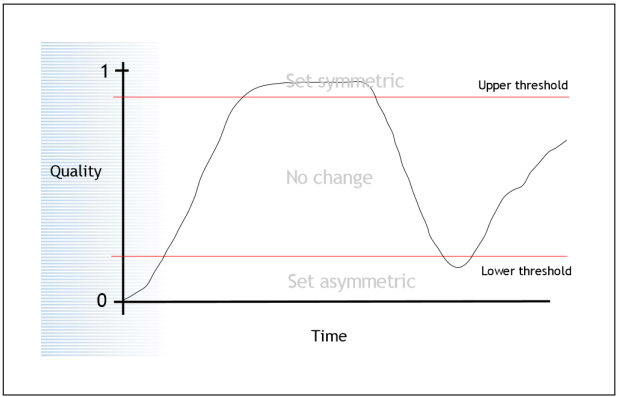
OLSR HELLO


0 1 2 3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
Reserved
Htime
Willingness
Link Code
Reserved
Link Message Size
Neighbor Interface Address
Neighbor Interface Address
..
Link Code
Reserved
Link Message Size
Neighbor Interface Address
Neighbor Interface Address

OLSR TC


0
1
2
3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
ANSN
Reserved
Advertised Neighbor Main Address
Advertised Neighbor Main Address

OLSR



http://www.olsr.org/docs/olsr-pres.pdf

- Links can be **symmetric** or **asymmetric**
- Status determined by number of `HELLO` messages received
- Hysterese avoids frequent routing updates

OLSR Challenges

Challenges

- Slow initialisation of routing tables (with 25 nodes!)
- Weak routes: hysteresis terminates connections to MPR
- Routing Loops
- Low throughput because long (bad) links are prefered (Minimum Hops)
- Selection of new (Internet-) gateway

Approaches

- Remove hysteresis
- Remove MPR concept (every node forwards messages)
- Result: better than OLSR, but
  - low throughput
  - gateway changes with routers

OLSR Optimisations

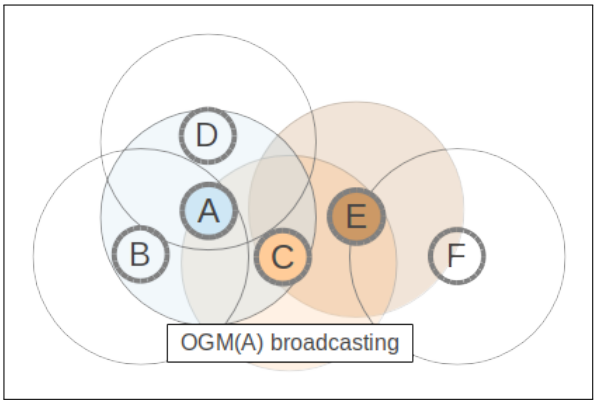
Fish Eye

- Additional (frequent) TC messages with low TTL (1,2,3)
- Local routing becomes optimal
- Significant performance improvements
- Minimum Hop is the wrong concept for wireless mesh

ETX

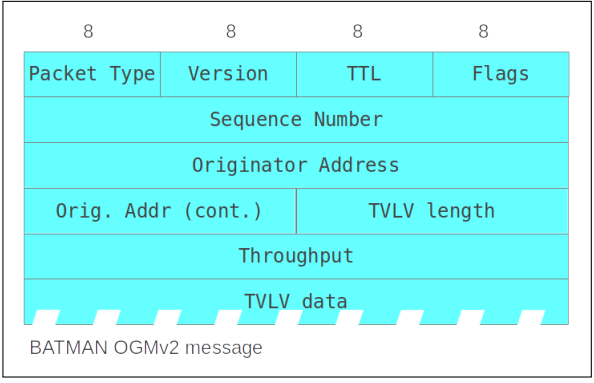
- Expected Transmission Count
  - Send testpacket to neighbor
  - Calculate probability of successful transmission (in both directions)
  - Calculate $ETX_{Hop} = 1/(p_f * p_r)$
  - Calculate $ETX_{Path} = \sum ETX_{Hop}$
  - Choose minimal ETX_{Path}
- Good routes, but loops under high load

B.A.T.M.A.N



- Node only needs to know the next hop towards a destination
- Network topology remains unknown
- Originator: node that generates OGM broadcasts
- Announces primary MAC address
- Originator List: all nodes of which OGMs were received

B.A.T.M.A.N



BATMAN OGMv2 message

- OGM default interval is 1 sec
- Link throughput is measured between neighbours
- Path selection is based on max throughput and recent OGMs
- (Internet-)Gateways are connected via tunnels and remain the same in case of changing links

Reading

Murray et al.: An Experimental Comparison of Routing Protocols in Multi Hop Ad Hoc Networks
2010 Australiasian Telecommunication Networks and Applications Conference