Quality of Service in Mobile Ad Hoc Networks – Myth or Reality?

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Presentation Outline

- What is Quality of Service (QoS) ?
- Existing QoS models and mechanisms
- Mobile Ad Hoc Networks and QoS
- What has been done on MANET QoS?
- Can't solve the problem? How about changing the problem…
- Conclusions

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What is QoS?

"*a networking term that specifies a guaranteed throughput level*" – Webopedia

"*The capability to control traffic-handling mechanisms in the network such that the network meets the service needs of certain applications and users subject to network policies*" – Networking Quality of Service and Windows Operating System, Yoram Bernet, New Riders 2001.

What is QoS?

"QoS is the network's ability to provide the level(s) of service promised to the users and/or applications"

Does today's Internet provide QoS?

YES!

Best Effort (BE) QoS.

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"Beyond BE" QoS mechanisms

Two basic types:

- ***Resource reservation***: network resources allocated according to an application's QoS request.
- ***Traffic Prioritization***: network traffic is classified and preferential treatment given to classes identified as having more demanding requirements.

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QoS Metrics

How to measure QoS?

Service attributes that can be used to quantify end-to-end performance:

- Delay
- Bandwidth
- Probability of packet loss (or packet delivery ratio)
- Jitter (delay variance)

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Existing QoS Models

Two Internet QoS Models:

- ***Integrated Services*** (IntServ)
  - Per-flow end-to-end guarantee
  - Resource reservation
- ***Differentiated Services*** (DiffServ)
  - Per-class service differentiation
  - Traffic differentiation and prioritization

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Integrated Services

- Uses an explicit mechanism (RSVP) to signal QoS requirements to network elements to reserve resources.
- 3 classes of service:

  Guaranteed (GS) – provides bounds on end-to-end delay

  Control Load (CL) – provides performance expected from an unloaded network

  Best-Effort (BE) – what you have today

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Differentiated Services

- Provides a simple and coarse method of classifying services of applications.
- Avoids scalability problems of IntServ.
- Per-flow state pushed to the edge of the network; traffic is treated on an aggregate basis – Per-Hop Behaviour (PHB)
- Two PHBs defined:
  - Expedited Forwarding(EF) [RFC3426] ≈ IntServ*GS*
  - Assured Forwarding(AF) [RFC2597]

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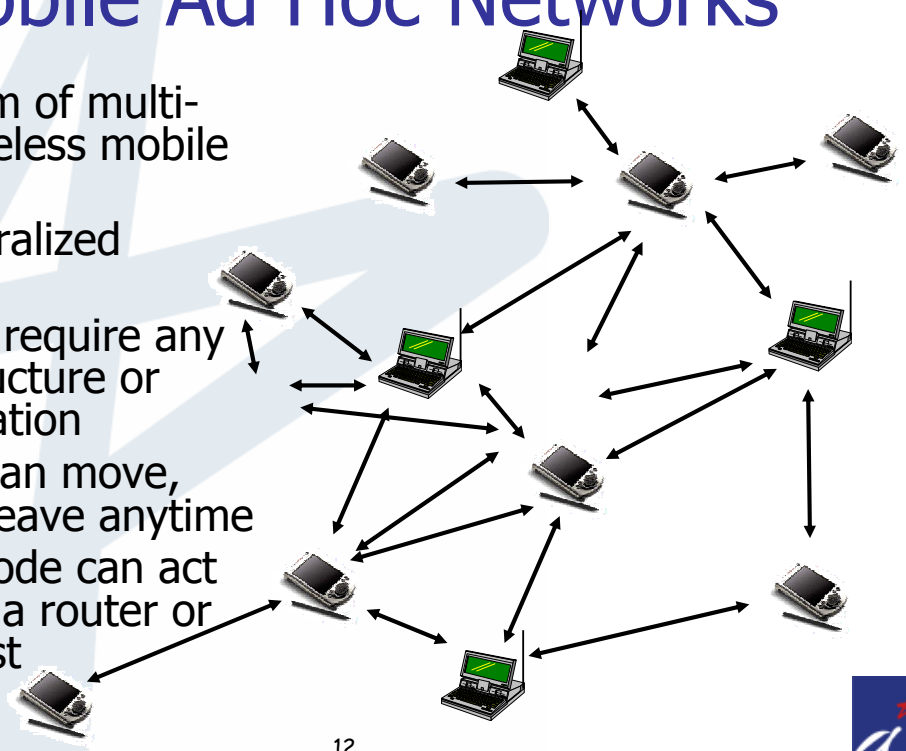
Mobile Ad Hoc Networks

- A system of multi-hop wireless mobile nodes
- No centralized control
- Doesn't require any infrastructure or base-station
- Nodes can move, join or leave anytime
- Every node can act both as a router or as a host



Characteristics and Issues

- Node mobility → dynamic topology
- Rapidly deployable and reconfigurable → complex route maintenance
- Bandwidth-constrained, variable capacity links → unpredictable links
- Hidden and exposed terminal problems
- Limited battery → energy-constrained
- Wireless media → limited physical security

Multi-Layer Problem

Physical layer

- adapt to rapid changes in link characteristics

Medium access control layer

- minimize collisions, allow fair access, provide reliable data transport over shared medium under changing rapidly conditions

Network layer

- determine & distribute routing information efficiently under changing link conditions and scarce bandwidth
- Interoperate with traditional non-ad hoc networks

Multi-Layer Problem

Transport layer

- Need to handle delay and packet loss arising from conditions unlike wired networks
- Packet loss due to transmission errors, not congestion
- Large variations in delay when route changes; not addressed by transport layer protocols' designs

Applications – need to be designed to

- Handle frequent disconnections and reconnections
- Adapt to widely varying delay and packet losses

Difficulties in Providing QoS

- Providing QoS beyond BE is a challenge even in a fixed network like the Internet where resource availability is more predictable.
- With resource availability constantly changing in MANETs, e.g. links breaking due to node mobility, trying to achieve the BE service similar to the Internet is already a challenge.

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MANET QoS Compromise

- Hard QoS in MANET is unlikely to be pausible.
- Soft QoS – allow network to fall short of QoS requirements for certain periods of time, up to a permitted threshold.
- Make QoS a function of the network resources and applications adapt to the "quality" of the network

MANET QoS Models

- Does not define specific protocols, algorithms or implementations
- Defines methodology and architecture for providing certain types of service
- Examples
  - FQMM (Flexible QoS Model for MANETs)
  - iMAQ (Integrated MANET QoS)
  - 2LQoS (Two-layer QoS model)

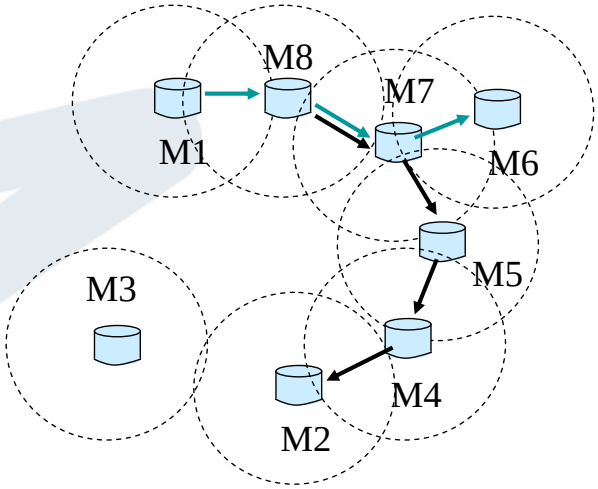
Flexible QoS Model for MANETs

Hybrid provisioning policy

- Traffic is divided into classes
- **IntServ**-like per-flow provisioning for the highest priority class
- **DiffServ**-like per-aggregate provisioning for the other classes

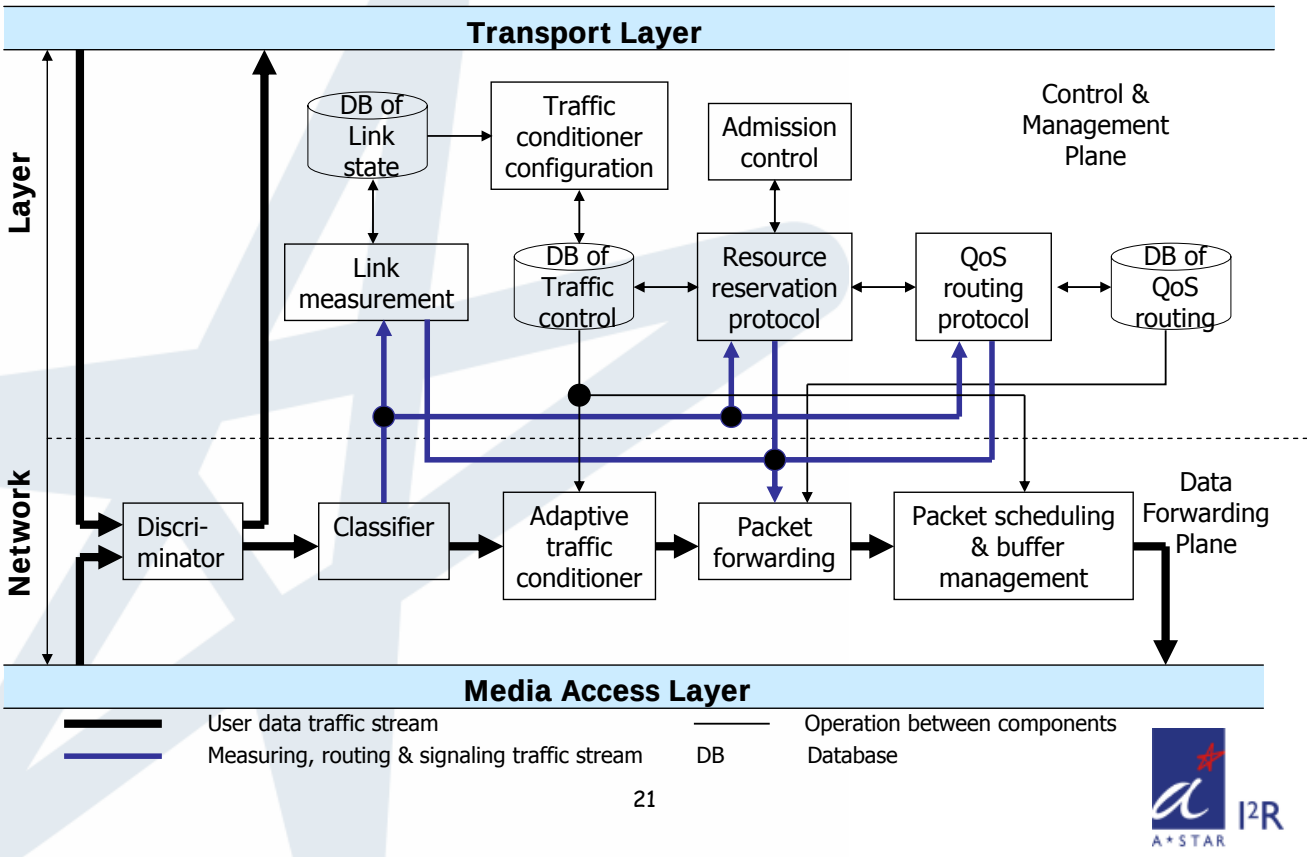
Three types of nodes

- ingress node: sender
- interior node: forwarder
- egress node: receiver



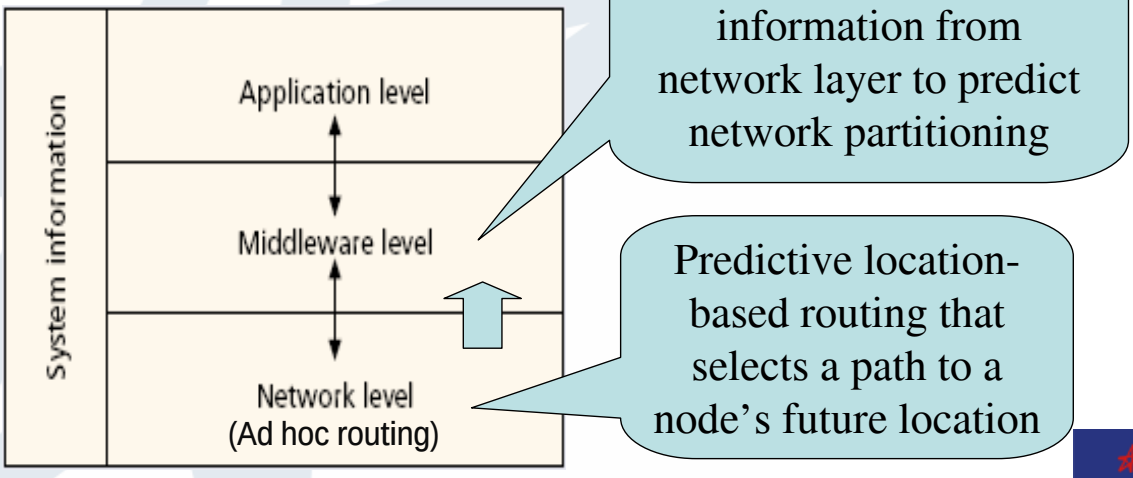
Connection	Ingress Node	Interior Node	Egress Node
C1	M1	M8, M7	M6
C2	M8	M7,M5,M4	M2

FQMM Architecture

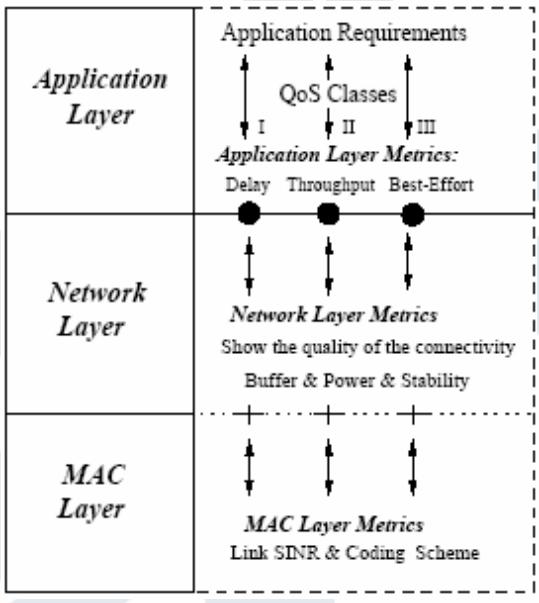


Integrated MANET QoS (iMAQ)

- Cross-layer architecture for multimedia traffic



Two-Layer QoS (2LQoS)



- Separates QoS metrics according to the layers (Apps, NET and MAC)
- Network's ability to provide QoS depends on resources available in the wireless medium and mobile nodes, and also stability of these resources.

QoS Routing in MANETs

Route selection with QoS metrics…

- QoS extensions to existing routing protocols, e.g. AODV, OLSR, and DSDV
- AQOR (Adhoc QoS On demand Routing)
- CEDAR (Core-Extraction Distributed Ad-hoc Routing)
- Multi-path QoS Routing

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QoS Extensions

Routing protocols implicitly select shortest path.

QoS for AODV (2000)

- Adding extensions to RREQ/RREP messages to specify *max delay* and *min bandwidth*.

QoS-enhanced OLSR (2003)

- Employs metrics beyond hop count (shortest path) in route selection

QoS-extension to DSDV (1999)

- Bandwidth calculation and reservation

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AQOR

- On-demand route discovery
- Signaling capabilities for resource reservations and maintenance
- Hop-by-hop routing

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CEDAR

- QoS routing for small to medium-sized MANETs
- Core formed with nodes approximating a *minimum dominating set;* each node picks one core node as its *dominator*
- Bandwidth availability info of stable links propagated to all core nodes
- Route is selected from source node's dominator to destination node's dominator satisfying requested bandwidth

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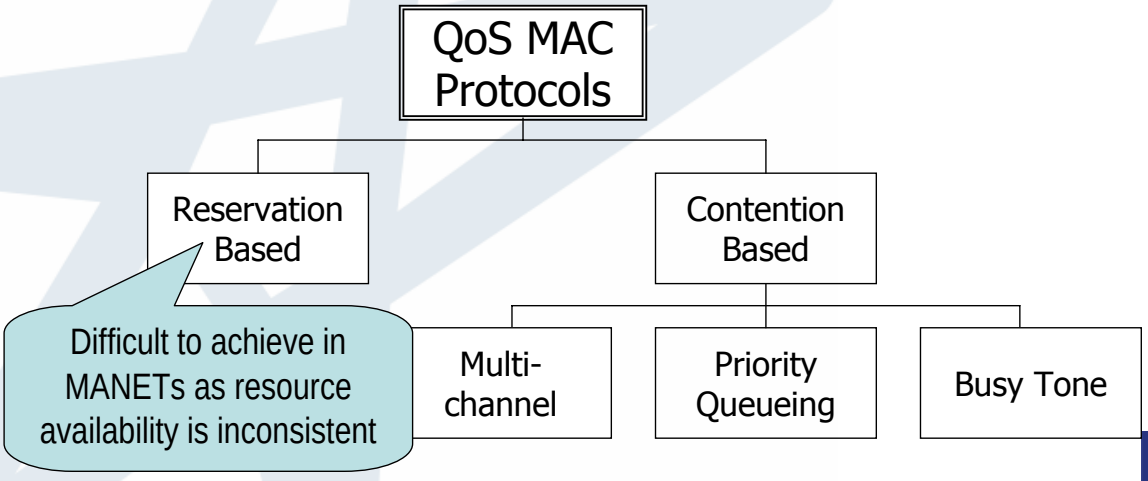
Multi-path QoS Routing

- Route discovery process selects multiple paths (if available, preferably disjoint) from source to destination
- Multiple paths can be collectively used to satisfy the required bandwidth (QoS) requirement
- Backup paths to immediately take over from the main path when links on the main path break

QoS MAC for MANETs

At least, a fully distributed scheme with no hidden/exposed terminal problem.



Contention-based QoS MAC

Priority queueing – IEEE802.11e based on CSMA/CA, extended with 4 queues – Access Categories 3(highest)~0(lowest); designed for WLANs, extended for use in MANETs [2004], e.g. Adaptive Fair EDCF, and measurement-based local data control and call admission control

Multi-channel – segregate whole data bandwidth into multiple sub-channels for different traffic classes, e.g. control and data [2003]

Contention-based QoS MAC

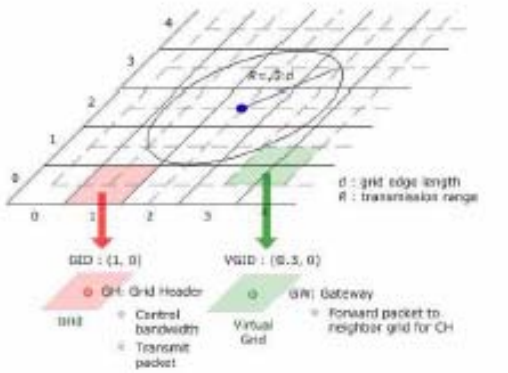
Busy tones [1999]

- Dual Busy Tone Multiple Access uses a signal outside data channel to indicate state of node or implicitly reserve bandwidth
- Black Burst (BB) Contention Scheme – a node contends by jamming the media with pulses of energy (BB) with length being a function of delay experienced by the node.

Topology Management

QoS-Grid [2003]

- Location-based(GPS) routing protocol
- Two-Tier-grid system to reduce each node's transmission power so as to enhance the bandwidth utilization and provide stable bandwidth guarantees.



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Uncertainty in MANETs

1. Unreliable and unpredictable wireless transmission media
2. Node mobility-induced topology and route changes; inaccurate locality info
3. Power control and energy constraints

There is no assurance that routes will be found/broken routes recovered within a given time

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Overcoming the uncertainties

Some existing techniques:

- Topology Control – varying (increasing) transmission range through power control → not straightforward and may increase contention
- Movement prediction → based on node movement patterns, try to determine the future location of a node but route to that location may not be available

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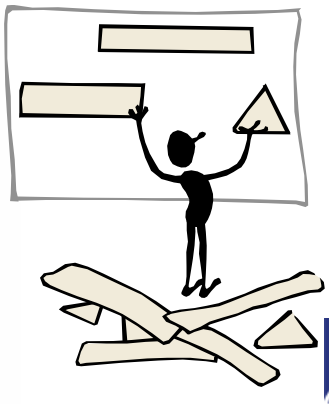
How to achieve "true" QoS?

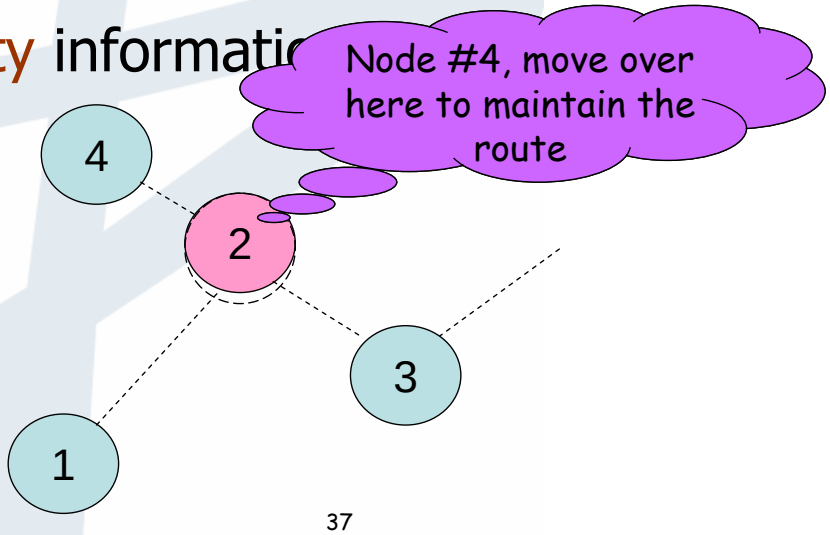
Can we provide hard QoS in MANETs?

Can't solve the problem? How about changing the problem…



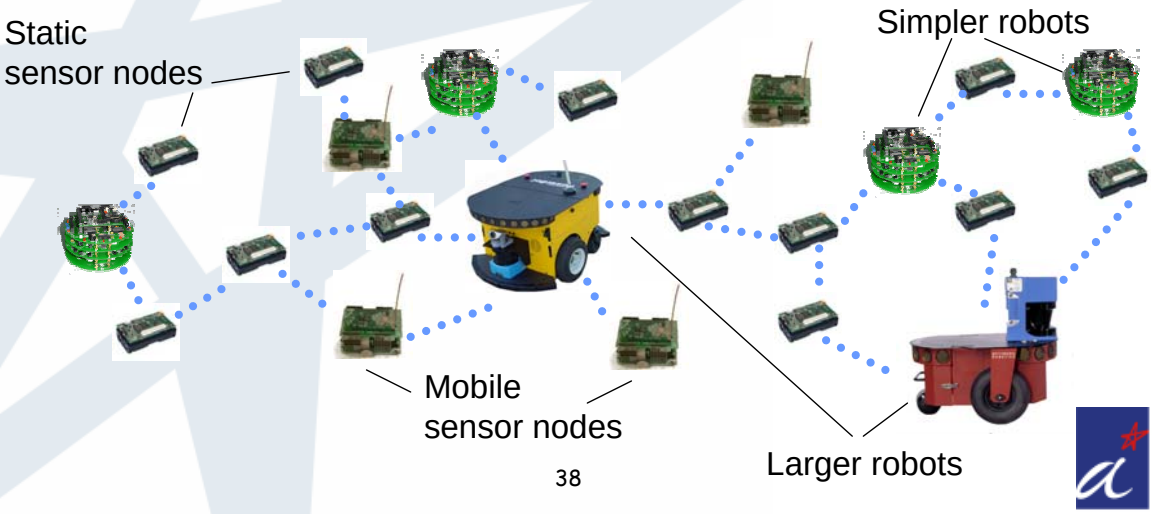
Control Node Movement

- The system/protocols have control over the movement of a subset of the nodes
- Locality informatic



Can we control the nodes?

- Swarms of mobile robots with sensors and actuators



Can we control the nodes?

- Unmanned autonomous vehicles (UAVs)
- Public transportation like buses and trains; less degree of control but the movement of these mobile nodes are predictable and can be moderated (speed up/slow down)

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