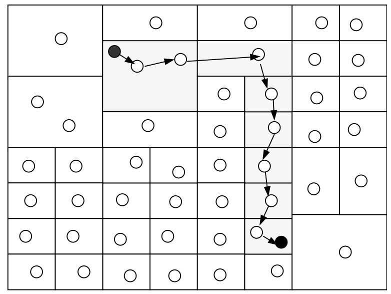
## Geographically Fixed QoS Routing (GFQR)

- An extension of GRID or fixed-zone-based routing protocols.
- The physical space is partitioned into cells
  - ❖ with any appropriate shapes and sizes,
  - ❖ according to the network topology, the available geographical information, the traffic conditions, etc.
  - ❖ Overlapping cells are allowed.



- Packets of a session are routed along a “geographically fixed route,” consisting of a set of cells.
  - ❖ black circles: source or destination,
  - ❖ white circles: backbone nodes for routing.
- GFQR can use any other topologies: e.g., triangular networks or
  - ❖ Webs: consisting of a star or tree intersecting concentric circles or polygons

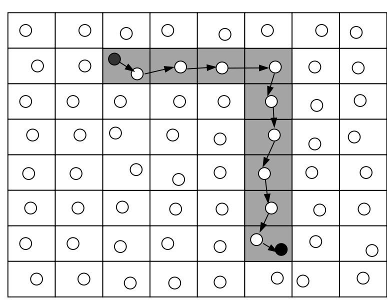
## Selective Table-driven Routing

- GFQR can employ on-demand routing, table-driven routing, localized routing, embedded routing, or selective table-driven routing to select a route
- Selective table-driven routing: mobile hosts that are
  - ❖ static or move relatively slowly,
  - ❖ located at critical locations,
  - ❖ and/or satisfying other criteria such as sufficient power level or favorable user options

  maintain routing tables, while other mobile hosts use other routing paradigms such as on-demand routing.
- The thresholds for selecting these table-driven mobile hosts are dynamically controlled, according to
  - ❖ traffic loads,
  - ❖ network size,
  - ❖ table size,
  - ❖ and/or other criteria.

## Geographical Reservation

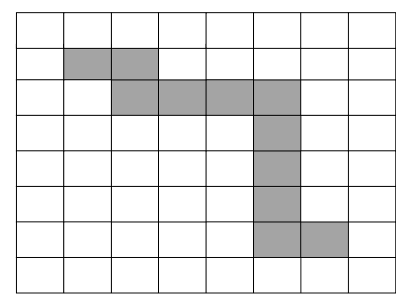
- GRACE: geographical reservation and clusterhead election.
- There can be multiple cells that overlap at a location.
- A clusterhead is elected from each of the cells, serving as
  - ❖ a resource broker, or
  - ❖ a backbone node for routing.



- Radio resources are reserved by a QoS session from the shaded cells.
  - ❖ white circles: clusterheads.
- Packets are routed using GFQR, where a cell can have more than one backbone node .

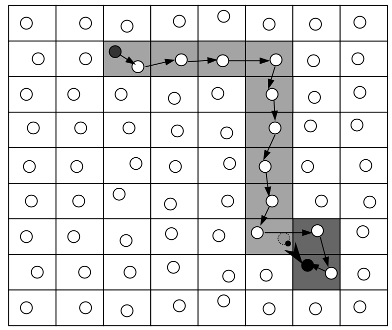
## Ad-hoc MPLS

- Ad-hoc MPLS: a lightweight version of MPLS with the virtual label-switched path (virtual LSP) extension.
- Purpose: to establish connection-oriented ad hoc networks or Internet for end-to-end QoS guarantees and traffic engineering.
- A virtual LSP consists of cells and/or nodes.
- Each cell is assigned a virtual IP address.
- A virtual LSP is specified by the virtual IP addresses of the cells and/or the IP addresses of the intermediate nodes.
- A virtual LSP is represented by the shaded cells in the figure.



# Ad-hoc MPLS (Conti.)

- The source and destination hosts may be mobile so virtual LSPs have to be extensible.
- The virtual LSP in the figure is extended by adding the dark cells in order to cope with the movement of the destination mobile host.
- Rerouting can be conducted to improve efficiency, especially when a loop is formed.
- Virtual reservations can be made for predicted extensions of virtual LSPs



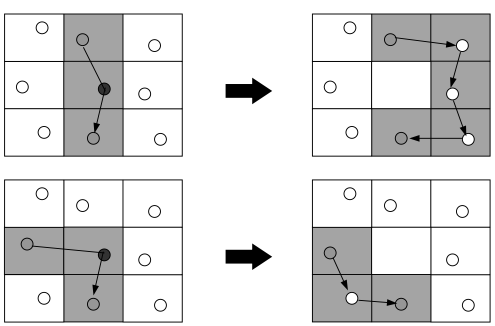
# Fault Models for Ad-hoc Distributed Systems

- Conventional fault models for distributed systems.
- New scenarios for wireless ad-hoc distributed systems (ADS):
  - ❖ Mobile hosts that violate IEEE 802.11 or other standards.
  - ❖ Noise or Interference for radio transmissions.
  - ❖ High moving speeds or uncovered locations.
  - ❖ Aggressive users that do not release radio resources fairly.
  - ❖ The transmission bandwidth available to a link is considerably reduced (but the link is not broken).
  - ❖ A certain area becomes empty so that relaying is not available.
  - ❖ The network topology becomes disconnected due to movements or shutdown of mobile hosts.
  - ❖ Appropriate mobile hosts that refuse to service others; a user turns off a mobile host during its service to other users.
  - ❖ Long delay and/or buffer overflow due to limited processing power shared by other local applications.
  - ❖ Mobile hosts infected by a virus that intends to disable the ADS or steal information.
  - ❖ And many others.

# Cell Protection

- Previous approaches for protection: node protection, link protection, path protection, or subpath protection.
- Cell protection: protecting a cell by using a protection sub-LSP bypassing it to replace a working sub-LSP traversing it.

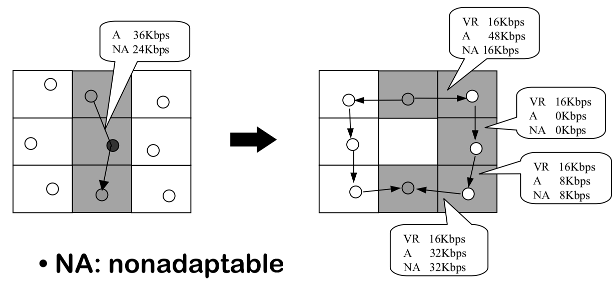
❖ A new paradigm for protection in ad hoc networks.



- The left sub-LSPs can be replaced by the right sub-LSPs.
- QoS can continue to be guaranteed even if a cell becomes empty, faulty, or interfered.

# Cell Protection with Virtual Reservation

- Virtual reservation: reuse the adaptable part of existing reservations.
- Multiple protection sub-LSPs can share a common virtual reservation.
- More than one protection sub-LSP can be established to protect a single sub-LSP.

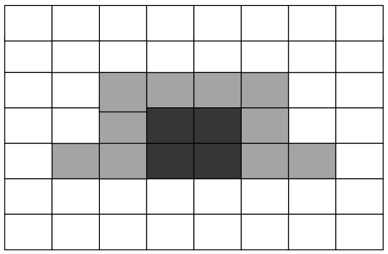



- NA: nonadaptable
- A: adaptable part
- VR: virtual reservations

The sum of the virtual reservations of all the protection sub-LSPs has to be equal to or greater than the nonadaptable part of the reserved bandwidth of the working sub-LSP.

## Geographical Area Protection (GAP)

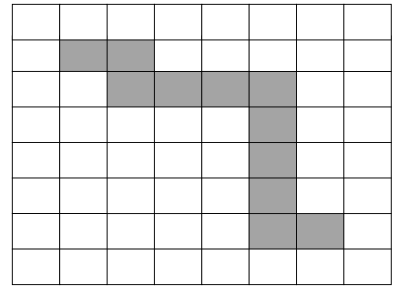
- GAP: protecting an area by using a protection sub-LSP that bypasses the area.
- ❖ Another new paradigm for protection in ad hoc networks.

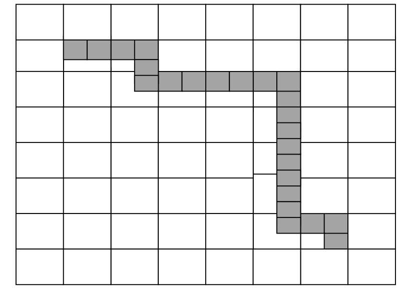


- The dark area is protected by the sub-LSP.
- QoS can continue to be guaranteed against any combination of faults within the area.

## Demand Engineering with Alternative Reservations

- Demand engineering: resource demands can be engineered in ad hoc networks by adjusting the transmission radii.
- An extension to traffic engineering for ad hoc networks.





- A (sub-)LSP can be replaced by another (sub-)LSP with different transmission radii, for example, to reduce the resource demands.
- Alternative reservation: The alternative set of reservations can share the nonadaptable part of the original reservations.

## A Network Currency Framework

- A new business model is required.
- Motivations for network currency:
  - ❖ Incentives to service other users,
  - ❖ Regulations between users and rules to share license-free bands,
  - ❖ Benefits for all users as a whole, e.g., preventing saturation,
  - ❖ Extra revenue/income for companies/users.
- (Dynamic) network prices for QoS reservations, high-priority sessions/packets, usage of radio resources, relaying, gateway to the Internet, etc. Biding is possible.
- Network currency can be transferred, sold, given away, etc, between users/companies/network governments.
- In addition to network dollars, network credit cards are necessary for timely payment.
- Network government(s) may be established to police the network etc, possibly with tax from users/companies.
- Standardization or collaboration from major vendors and the majority of users are required.

## Conclusions and Future Directions

- Proposed a QoS ad-hoc networking framework
- Presented GFQR, SRRS, selective table-driven routing, fault models for ADS, and a network currency framework
- Illustrated GFQR, ad-hoc MPLS, GRACE, cell protection, GAP, virtual reservation, alternative reservation, demand engineering
- Future research:
  - ❖ Refinements of the proposed frameworks, schemes, and mechanisms
  - ❖ Comprehensive simulations for the proposed approaches
  - ❖ Experiments on a *wireless NOW* testbed