

## Centralized Routing for Resource-Constrained Wireless Sensor Networks

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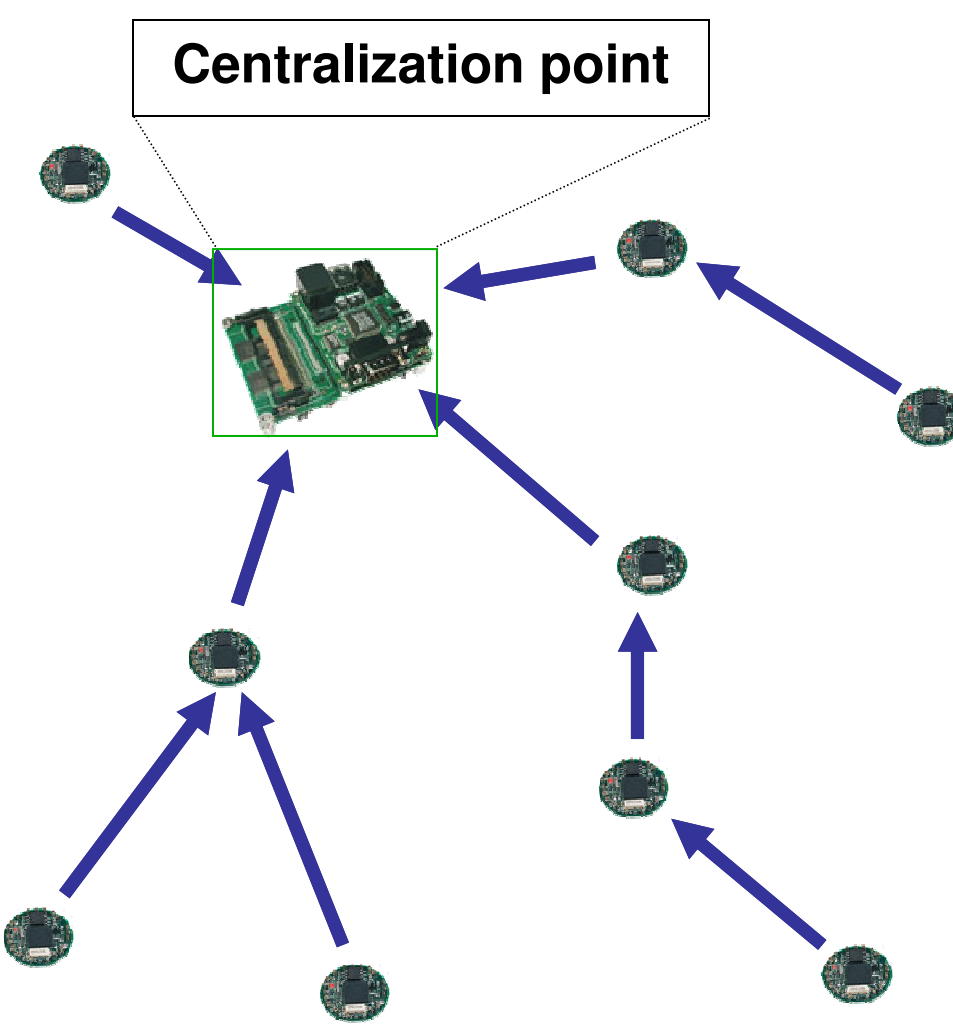
### CentRoute: Centralized routing protocol for motes

#### Why centralized routing for motes

- **Heterogeneous systems:** Collections of *motes* and *microservers* working together
- **Utilize heterogeneity:** *shift routing decisions* from resource-constrained motes to resource-rich microservers

#### Centralized routing

- Addresses problems of distributed protocols
- Provides *global view* of the entire mote network at each sink



#### Heterogeneous Design Principle

Use the advantages of one platform to *offset* the disadvantages of another

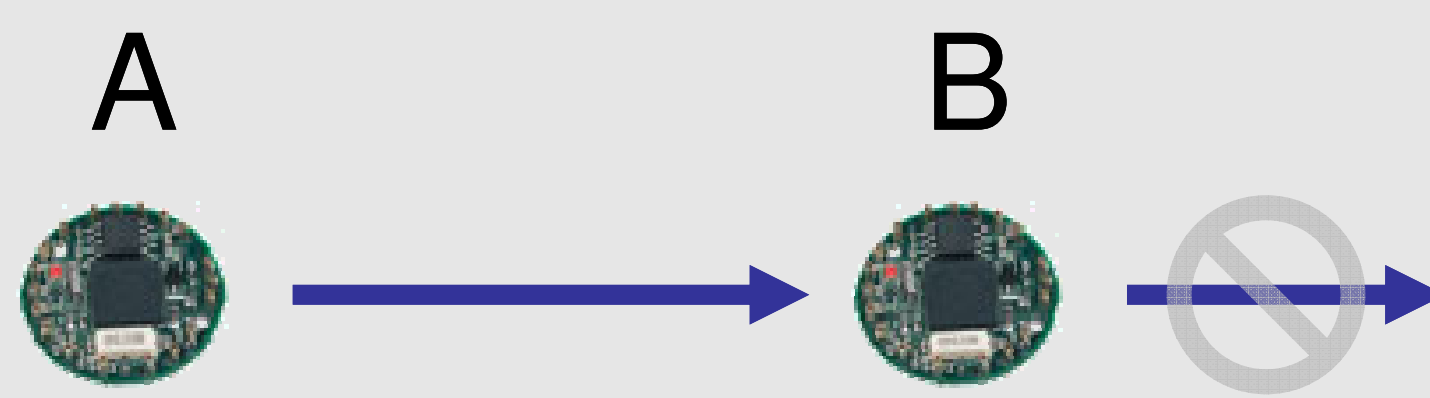
Corollaries for mote routing:

- **Centralize** decision making on a *microserver* to make routing decisions based on a *complete* set of information
- **Reduce** memory requirements of motes
- **Program** a significant part of the protocol in a *familiar* and resource-rich *32-bit environment*

### Problems with Distributed Proactive Routing on Motes

#### Distributed Decision-Making with RAM Constraints

- **Mote-specific** problems:
  - *Distributed decision making* in conjunction with *storage constraints* leads to routing *instabilities* and *inconsistencies*
  - *Limited RAM* also creates *scalability challenges* in terms of network density and network size
- **Additional** problems
  - *Proactive nature* leads to increased energy consumption
  - *Distance-vector* leads to count-to-infinity scenarios and routing loops



Node A *has* node B in neighbor table and as a next hop to a destination

Node B *doesn't have* node A in neighbor table and thus *doesn't forward* the packet further

- Selection of the next hop to a destination is based on *neighbor table*
  - Memory requirements are  $O(\text{neighborhood size})$
- **Memory constraints** place upper bound on table size
  - Cache eviction policies used
  - Subject to *thrashing*, especially in dense networks
  - Leads to routing instabilities ("flapping")
- Independent decisions by nodes based on artificially constrained information lead to *inconsistencies*

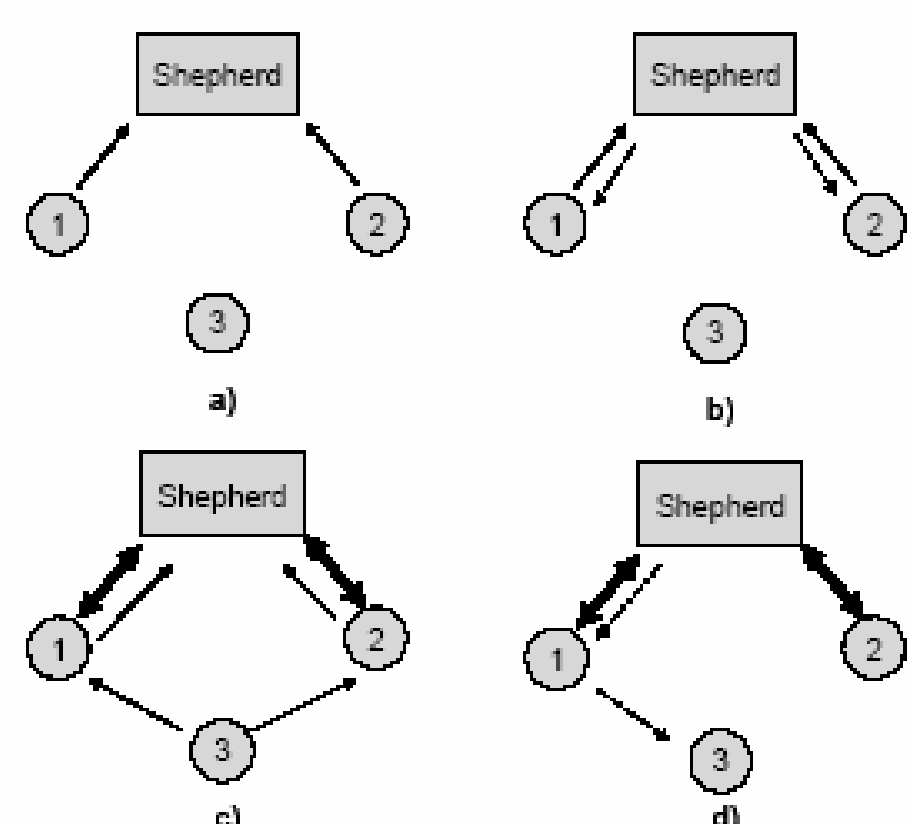
### CentRoute: Protocol Details and Performance

#### Protocol Details

- Runs on *both* motes and their sink (microserver)
  - Motes forward *control data* to microserver
  - Decision-making logic implemented *exclusively* on microserver
- **On-demand** protocol
  - Tree maintained by *data packets*
- **Dynamic single-sink** support
  - Sink selected at *runtime*
  - Motes only send data to (and keep state for) one sink at a time
  - Multi-sink ambiguity resolved in *microserver tier*
- **Source Routing** used in both directions

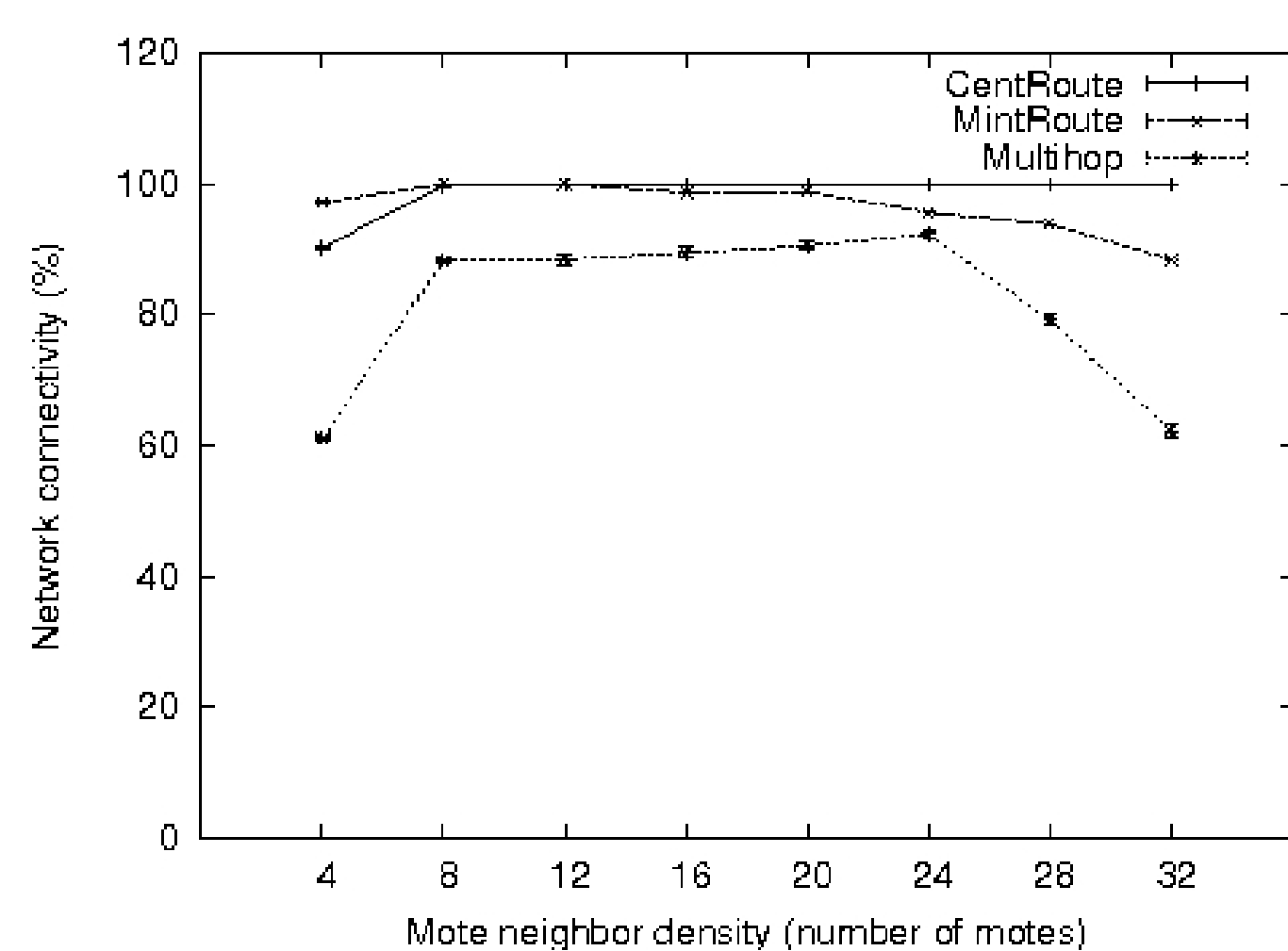
#### Tree Formulation

- Motes broadcast beacons *only* when they wish to join a tree
- Any motes *attached* to the tree *forward* join beacons towards shepherd via unicast
- Microserver picks *best path* using an ETX metric and sends a *unicast source-routed reply* to the mote
- Mote attaches to tree and uses the *last mote* on the reverse path as its *parent*

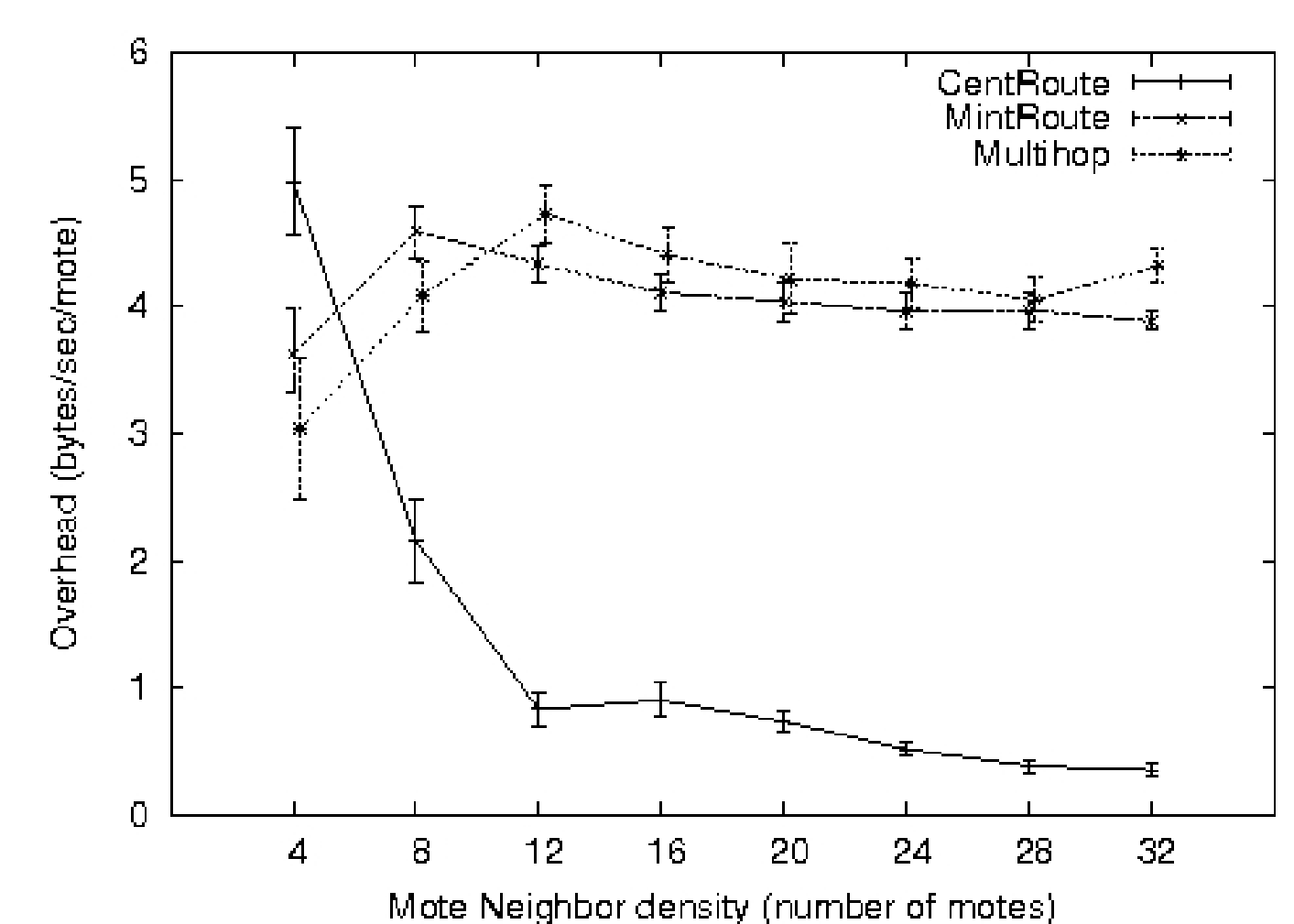


The CentRoute *phased-join* operation

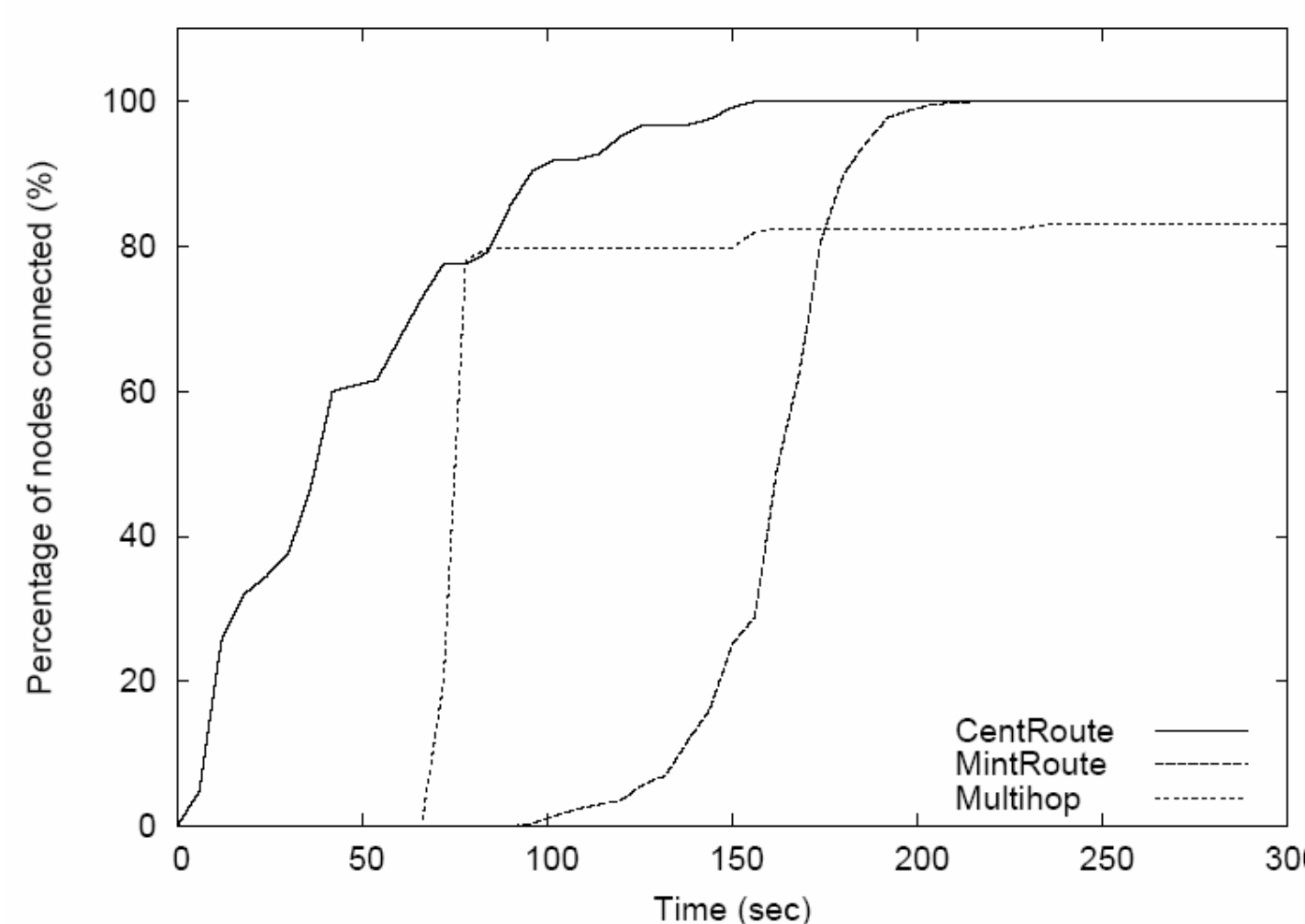
#### Performance



Improved connectivity at *medium and high densities* due to lack of per-mote neighbor state



Very low control overhead due to *on-demand* nature



Quickly connects large part of the network

Usage (bytes)	RAM	ROM	RAM cost per neighbor
CentRoute	1274	17184	0
MintRoute	1689	12588	18
Multihop	1560	17292	19

Lower memory usage on the mote due to absence of  $O(N)$  state

Neighbor density (motes)	CentRoute loop prob. (%)	MintRoute loop prob. (%)	Multihop loop prob. (%)
4	0	0.47	2.11
8	0	0.01	1.92
12	0	0.02	1.88
16	0	0.03	2.48
20	0	0.03	3.65
24	0	0.04	4.8
28	0	0.04	3.12
32	0	0.02	7.27

Eliminates loops through *centralized decision making*, *source routing* and absence of *any* mote *decisions*

#### Current status & Future Work

##### Current Status

- Deployed at Botanical Gardens.
- Field deployment at James Reserve pending

##### Future work

- Utilize global view & centralization nature to design a transmission scheduler for Cyclops image transfer over multiple hops