Title
Mote Herding for Tiered Wireless Sensor Networks

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Mote Herding for Sensor Networks

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Mote Herding: A system architecture for Tiered Wireless Sensor Networks

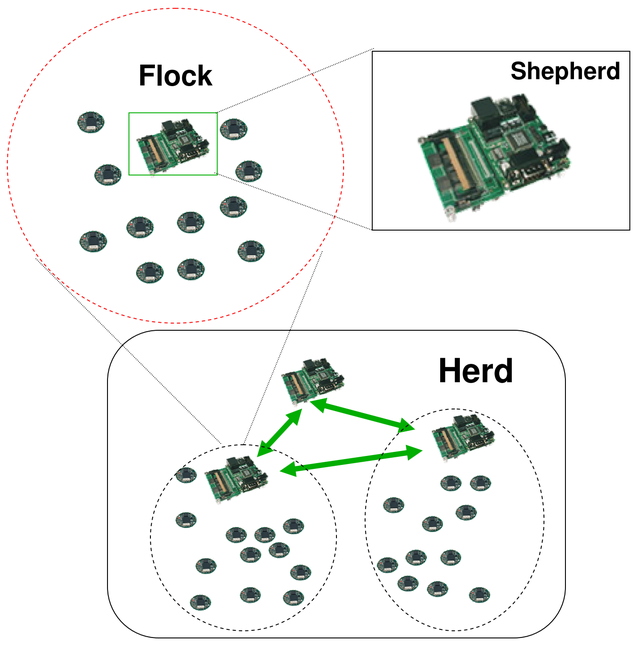
Mote Herding

Tiered systems: Collections of *motes* and *microservers* working together

Mote Herding explores guidelines to clarify how services should be developed in tiered systems

Architectural abstractions

- **Flock**: a collection of *motes* that connects to a microserver via a multihop tree
- **Shepherd**: a *microserver* responsible for a *single flock*. Shepherds connect to each other using *IP-based routing* over 802.11
- **Herd**: the collection of *flocks* and *shepherds* that forms the *entire* mote/microserver network



Design Principle

Shift system complexity from motes to microservers for those operations that require distributed decision making on the motes

Corollaries:

- **Centralize** decision making on a *microserver* to make decisions based on a *complete* set of information
- **Reduce** volatile state required for *system functionality* on motes
- **Utilize** computational and communication resources on microservers to support more *complex functionality*
- **Program** a significant part of the system in a *familiar* and resource-rich *32-bit environment*

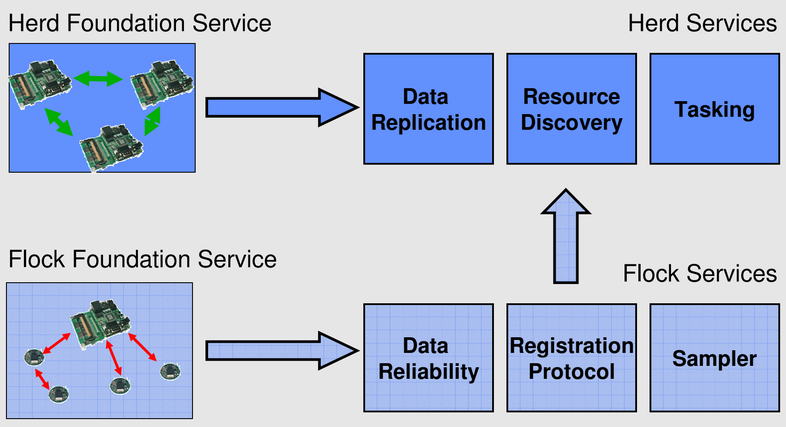
Mote Herding Services

Flock Services

- Operate on a *flock* under supervision of *a shepherd*
- Hybrid: code resides on *motes* and *microserver*
- Can use other services in the same flock but *cannot* interact with motes on *other flocks*
- Emphasize *master-slave* relationship between microservers and motes

Flock Foundation service: Mote Routing

- Provides *bi-directional* routing from motes to their shepherd
- Centralized protocol: *shepherd* makes *all* routing decisions
- Lack of distributed decision making on motes improves *stability* and *consistency*



Herd services

- Operate on the *entire* network
- Code resides only on *microservers*
- Interface to the mote network via *appropriate flock services*
- Allow for *distributed* and *collaborative* decision making between microservers

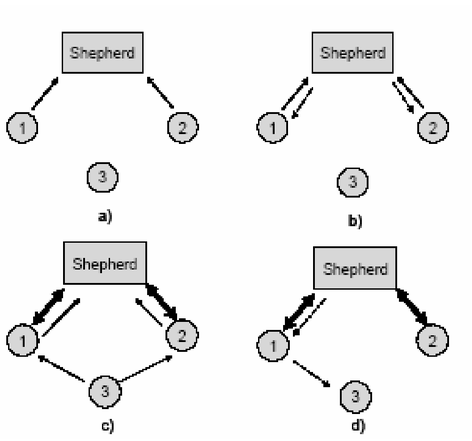
Herd Foundation service: Microserver State Replication

- StateSync: a reliable *state synchronization* protocol
- Allows *state sharing* on the microserver level for information pertaining several flocks
- Provides each microserver with a *global state view*

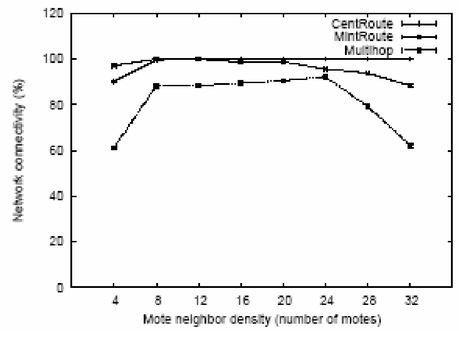
Service Details and Performance

CentRoute

- **Centralized** routing protocol based on *source routing*
- Motes broadcast beacons *only* when they wish to join a tree
- Any motes *attached* to the tree *forward* join beacons towards shepherd via unicast
- Shepherd picks *best path* using an ETX metric and sends a *unicast reply* to the mote
- Mote attaches to shepherd and uses the *last mote* on the reverse path as its *parent*
- Multi-shepherd ambiguities resolved on *microserver network*



The CentRoute *phased-join* operation



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

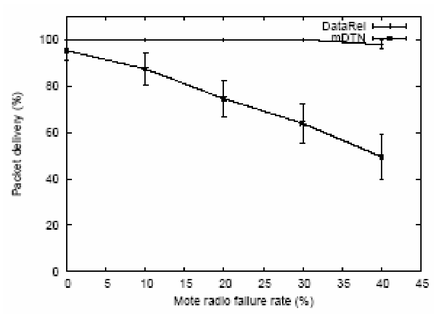
Loop avoidance improved by combination of *centralized decision making*, *source routing* and absence of *any* mote *decisions*

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

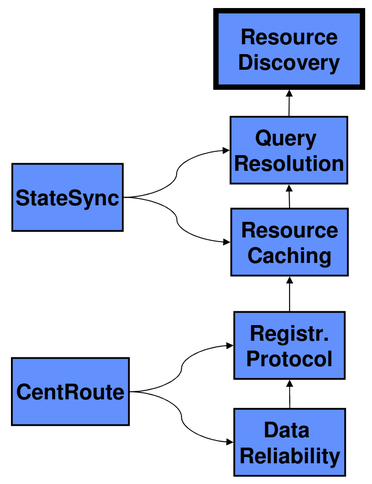
DataRel

- **End-to-end** mote data reliability protocol
- Can deliver 100% to the data at up to 30% *link failure* rates
- Low buffer usage and complexity compared to hop-by-hop protocols (mDTN)



ResDisc

- **Resource Discovery** herd service based on three subservices
- **Registration protocol** *registers* mote resources with *shepherd*
- **Resource caching** *exports* local flock resources and *imports* remote flock resources
- **Query resolution** replies to client queries based on information from resource caching



Future Work

- Implementing more services (data replication, tasking, system monitoring)
- Implement a coordinated imaging application using Cyclops and larger more powerful cameras

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