Wireless Mobile Ad-hoc Sensor Networks for Very Large Scale Cattle Monitoring

Milena Radenkovic &
Bartosz Wietrzyk

The University of Nottingham

EPSRC Engineering and Physical Sciences Research Council

Talk Plan

- Motivation
- Architecture
- Protocol

Scale of Beef and Milk Production in United Kingdom

- 5,709,000 cattle (2003)
- Soon to increase as the EU export ban is released
- 19.7 kg beef eaten per capita in UK in 2002 (19.6 in EU)

Loses Caused by Animal Diseases in United Kingdom

- Bovine Spongiform Encephalography (BSE) in 1986
  - 200,000 animals infected
  - Pre-emptive slaughter of 4,500,000 animals
- Foot-and-mouth disease (FMD) in 2001
  - Eradication of 4,000,000 animals

Objectives of Nationwide Cattle Monitoring System

- Detecting outbreaks of animal diseases
- Indicating general animal health issues
  - Lameness
  - Mastitis
  - Other infection and metabolic diseases

Current State of Cattle Monitoring

- British Cattle Movement Service
  - Recording cattle births, deaths and movement
  - Manual input over web interface, e-mail, post
  - Ability to upload data in gross
  - Entries for over 5,000,000 animals
  - No animal proximity data
- Farm level monitoring systems
  - Non obligatory
  - Heterogeneous
  - Poorly integrated

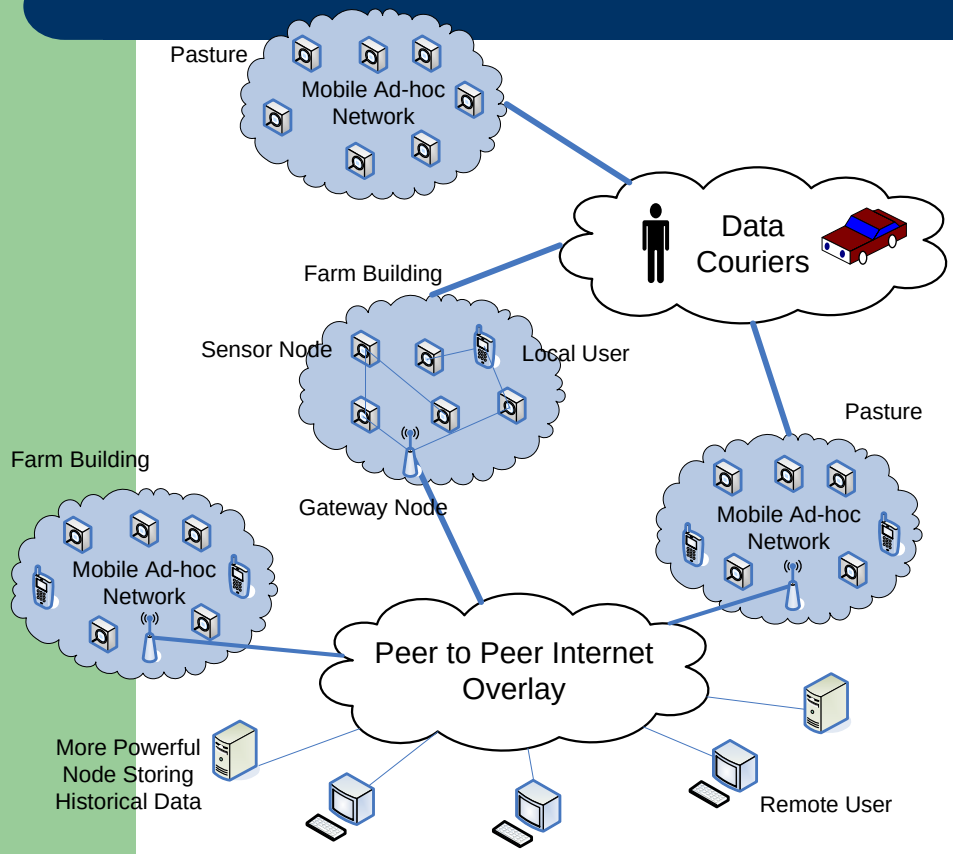
Requirements and Challenges

- Limited maintenance and deployment cost
- High reliability
- Limited negative impact on animals
- Security

Talk Plan

- Motivation
- Architecture
- Protocol

Proposed Architecture



- No centralised component
- Multiple MANETs containing mobile sensor nodes
- Animal mounted sensor devices acquiring, storing and processing data related to animals' health and location, caching measured and queried data
- Extendable by pluggable modules
- More powerful nodes storing historical data, acquired by querying a subset of topology

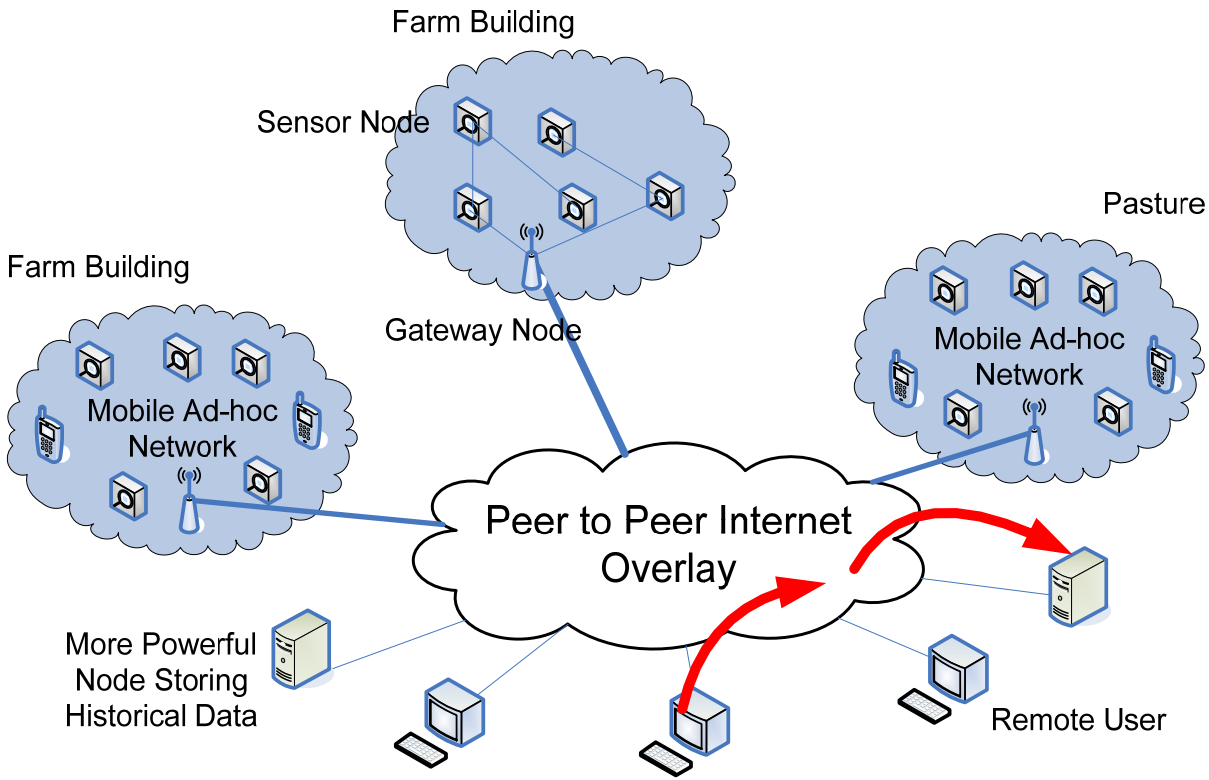
State of an Animal

- Comprises detected events (e.g. diseases), ear tag ids of approached animals, timestamps of these meetings etc.
- Most recent state cached on a number of other animal mounted nodes
- Historic states archived on the more powerful fixed nodes

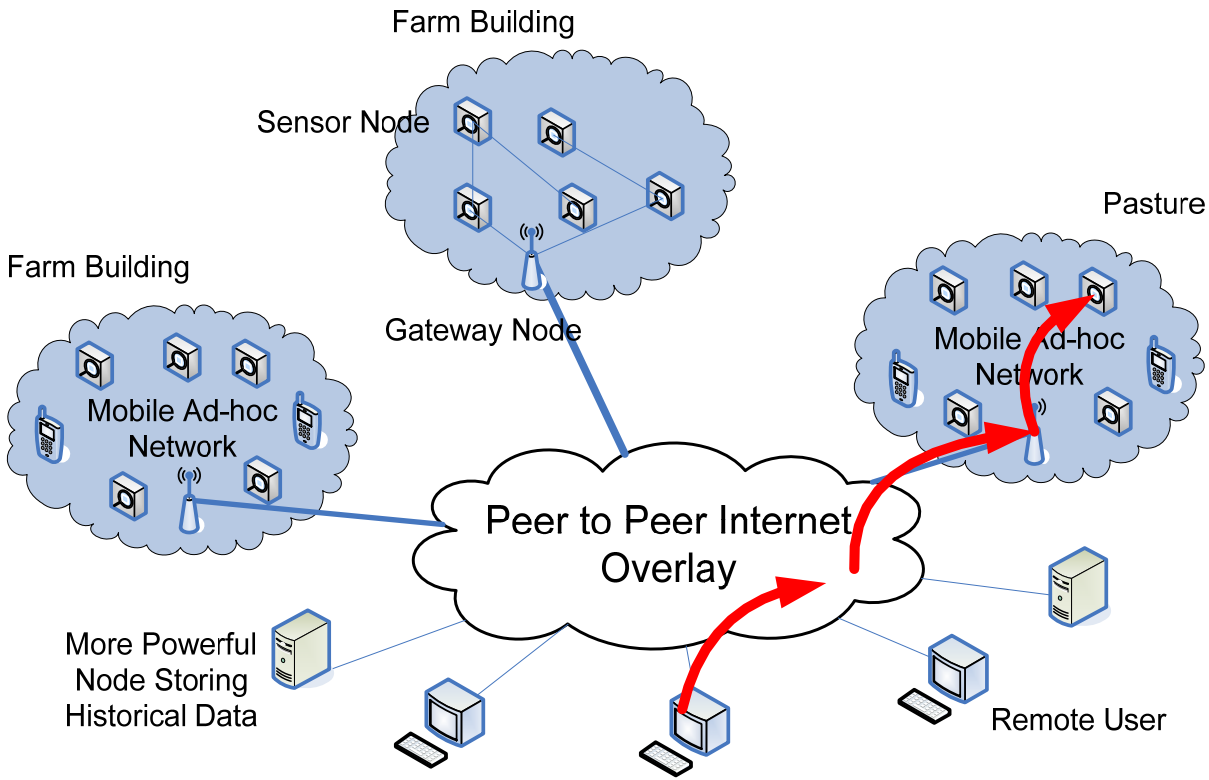
Users

- Stockmen, farmers, slaughter workers, people involved in animal trade etc.
- Issue queries concerning a particular animal, animals on a certain area, or animals met by a particular animal
- Can issue queries over Internet or on a Field

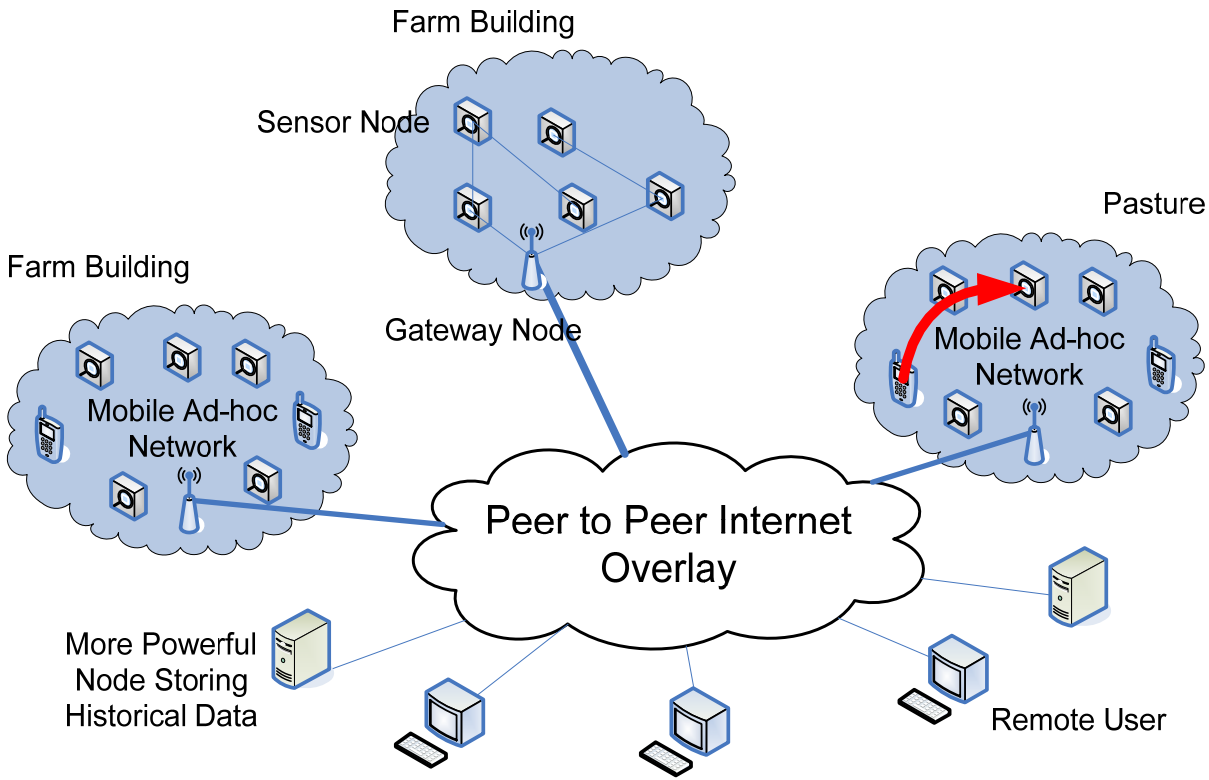
Query over Internet



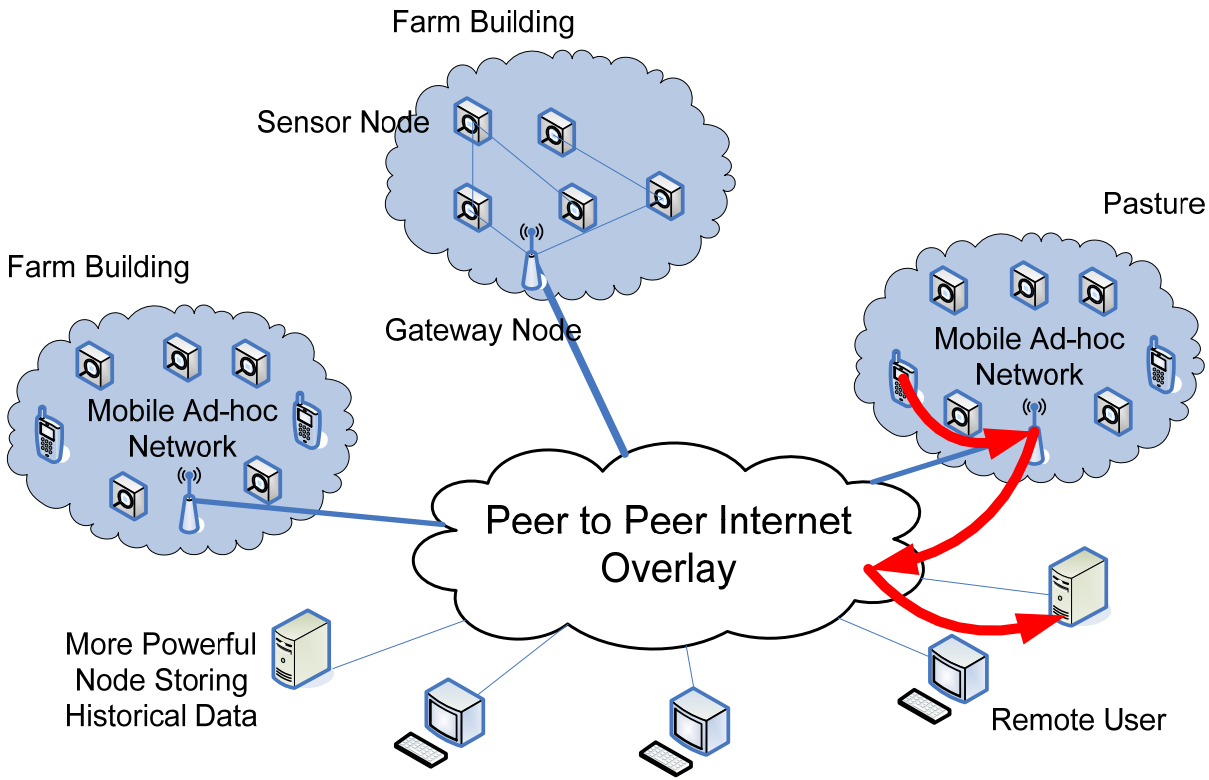
Query over Internet



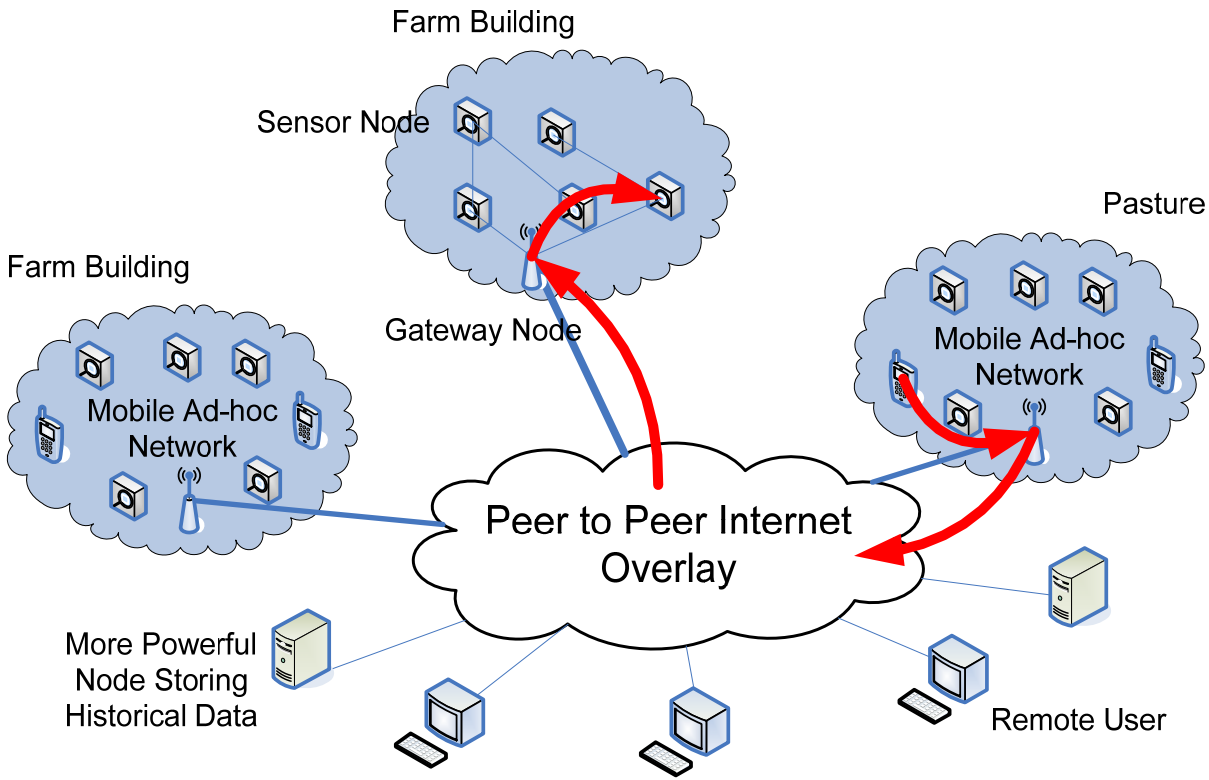
Query on a Field



Query on a Field



Query on a Field



Talk Plan

- Motivation
- Architecture
- Protocol

Routing (DHT)

- Within a single MANET (e.g. pasture) or set of MANETs connected with Data Couriers
- Each node has a unique 128 bit id
- Each message has a 128 bit key
- Objective: route a message to a node with the id numerically closest to the message's key

Leaf Set and Routing Table

Node Id 10233102

Leaf set	SMALLER	LARGER	
10233033	10233021	10233120	10233122
10233001	10233000	10233230	10233232

Routing table

-0-2212102	**1**	-2-2301203	-3-1203203
0	1-1-301233	1-2-230203	1-3-021022
10-0-31203	10-1-32102	**2**	10-3-23302
102-0-0230	102-1-1302	102-2-2302	**3**
1023-0-322	1023-1-000	1023-2-121	**3**
10233-0-01	**1**	10233-2-32	
0		102331-2-0	
		2	

Self-organized Caching

- State
  - Contains data related to animal's health and location
  - Is identified by animal's id and timestamp
  - Every node stores its own state and up to *k* states from other nodes
  - Nodes give priority to states with ids numerically closest to their ids
- Passive caching
  - Nodes cache states from received, forwarded and overheard packets
- Proactive caching
  - Nodes exchange proactively states with their neighbours according to the storage strategy of these neighbours

Proactive Caching

1) A node detects no traffic for t_1
2) It sends a beam packet with the list of states it stores (ids + timestamps)
3) Recipients of the beam packet send states expected to be stored by the sender of the beam packet after time t_2 (taking into account what they overhear)

$$t_1 = T_1 + T_2 * S + T_3 * j$$

$$T_1 > T_2 > T_3$$

$$t_2 = \frac{T_2}{n} + T_3 * j$$

$$T_2 > T_3$$

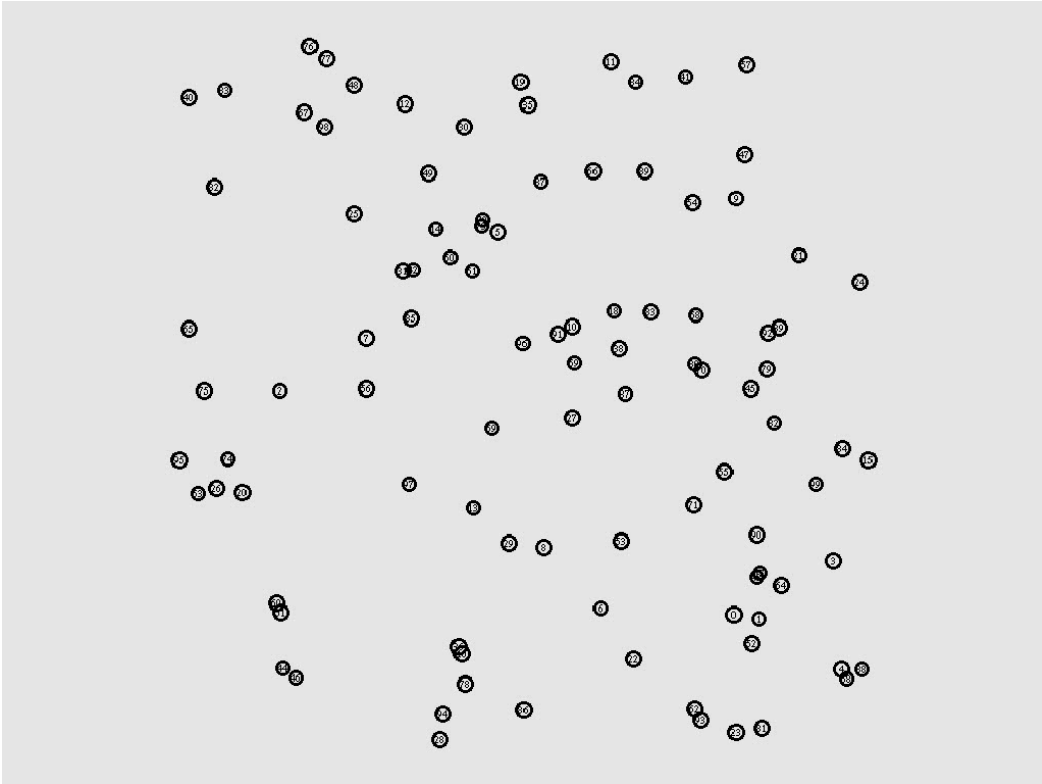
Advantages of Proactive Caching

- Improved dissemination of states (when no queries)
- Exploiting mobility of nodes
- Exploiting temporary availability of nodes

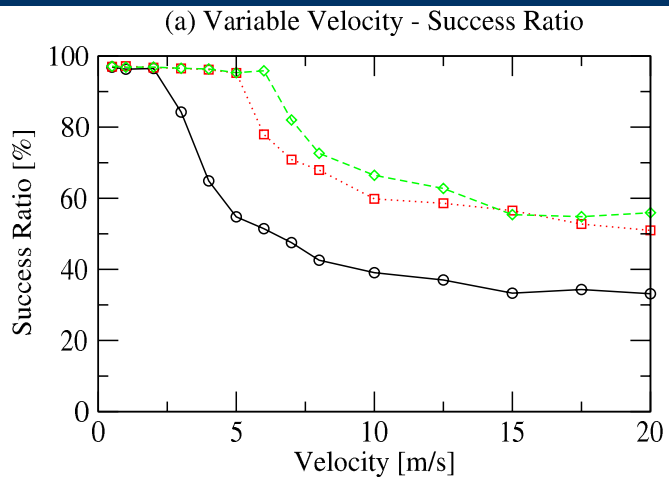
Simulation Setup

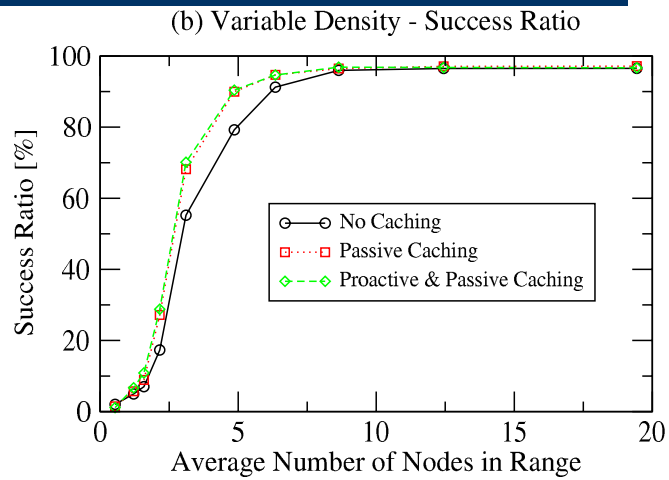
- 100 nodes on 1 km^2 for 1200 s (ns-2)
- Random velocities from 0.1 m/s to 2 m/s (Random Waypoint Model)
- What happens:
  - Nodes join DHT (1 every second)
  - Start of proactive caching after 100 s
  - Random queries every 10 s (each node) – start after 300 s
- Other parameters
  - T_1=15s, T_2=0.1s, T_3=0.001s, t_{max}=1000s, $t_{min\ gap}$=0.01s
  - Size of cache (k)=10 states, Size of state=1024B

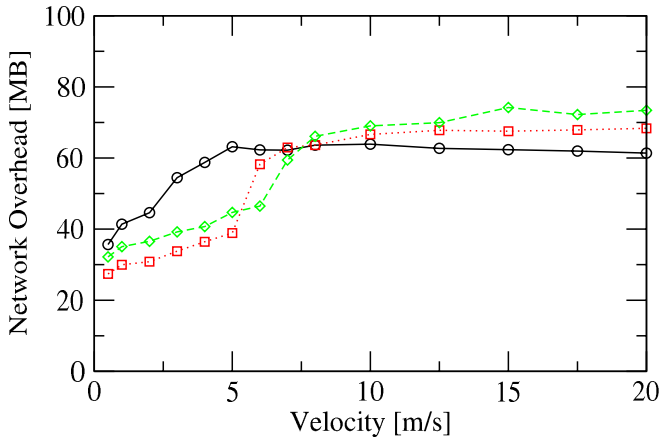
Node Movement

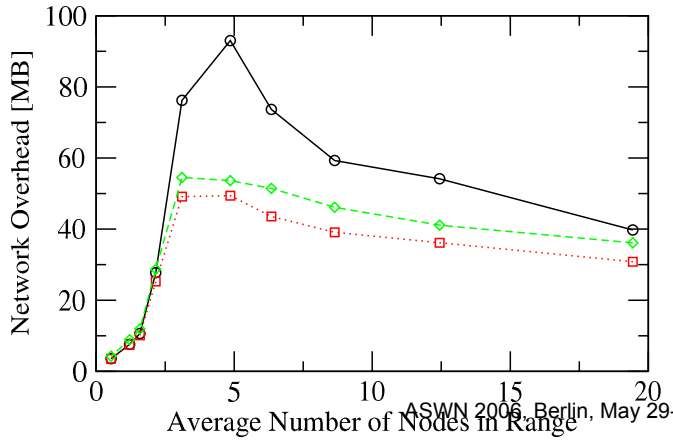


Simulation Results I



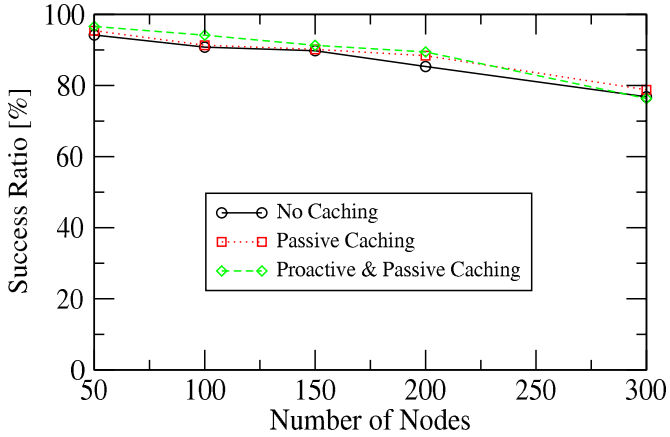




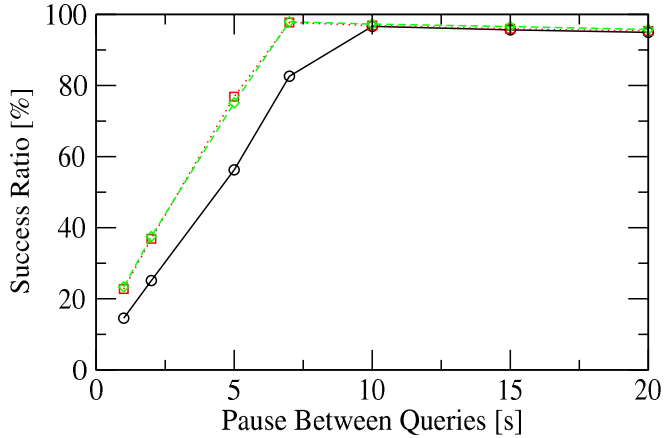


Simulation Results II

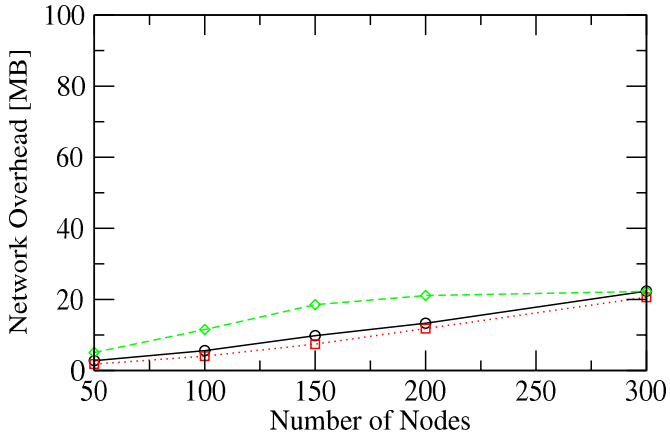
(a) Variable Number of Nodes - SR



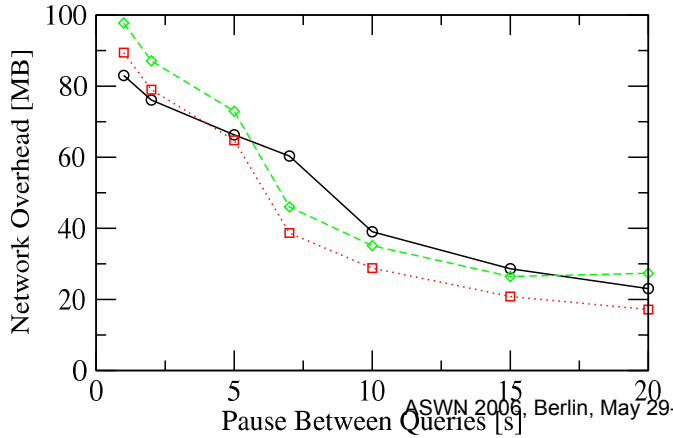
(b) Variable Frequency of Queries - SR



(c) Variable Number of Nodes - NO



(d) Variable Frequency of Queries - NO



Summary

- Novel scalable, self-organized architecture for nationwide cattle monitoring
- DHT based protocol addressing partitioning in MANETs

Questions + Answers