A Declarative Perspective on Adaptive MANET Routing

Changbin Liu, Yun Mao, Mihai Oprea, Prithwish Basu, Boon Thau Loo

University of Pennsylvania, BBN Technologies

Motivations

- **Variety of MANET routing protocols**
  - Reactive (DSR, AODV)
  - Proactive (LS, OLSR, HSLS)
  - Epidemic
  - Hybrid (ZRP, SHARP)
- However, a one-size fits all MANET protocol **DOES NOT** exist:
  - Variability in network connectivity, wireless channels, mobility
  - Wide range of traffic patterns

Approach

- **Policy-driven hybrid protocols**
  - Generic set of policies (rules) for selecting and switching among different routing protocols due to network conditions
  - Build adaptive MANET routing protocols from simpler components
- **Declarative framework**

Background

- **Declarative Networking [Loo et. al., SIGCOMM'05]:**
  - Use a database query language to express declarative specifications of networks
  - Declarative specifications are executed by distributed query engine (Click execution model) to implement network protocols

Why Declarative for MANETs?

- **Compact representation of protocols**
  - Orders of magnitude reduction in code size
    - Chord in 47 rules
    - MANET routing protocols in a few rules
- **Easy customization for adaptive MANETs**
  - Policy-driven hybrid protocols
  - Component-based routing

Network Datalog (NDlog) Example

R1: reachable(@S,D) ← link(@S,D)

R2: reachable(@S,D) ← link(@S,Z), reachable(@Z,D)

link(@a,b) – "there is a link from node *a* to node *b*"

"For all nodes S, D:
If there is a link from S to D, then S can reach D".

reachable(@a,b) – "node *a* can reach node *b*"

- Input: link(@source, destination)
- Output: reachable(@source, destination)

Network Datalog (NDlog) Example

R1: reachable(@S,D) ← link(@S,D)

➔ R2: reachable(@S,D) ← link(@S,Z), reachable(@Z,D)

"For all nodes S,D and Z,
If there is a link from S to Z, AND Z can reach D, then S can reach D".

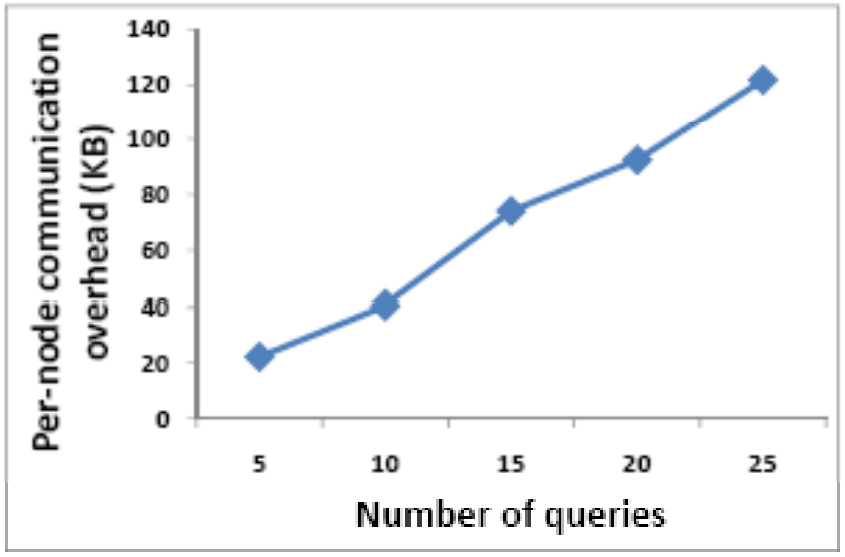
- Input: link(@source, destination)
- Output: reachable(@source, destination)

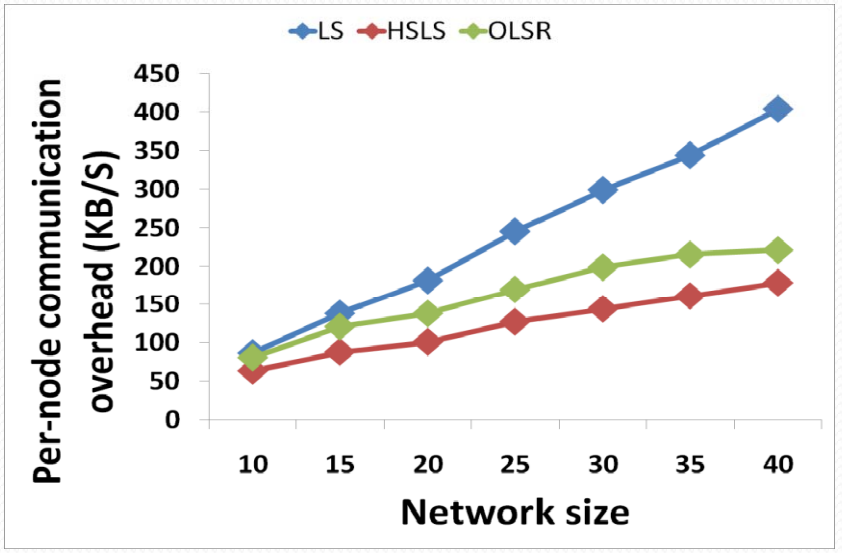
Declarative MANET protocols

- **Reactive**
  - **DSR (Dynamic Source Routing) (11 rules)**
- **Proactive**
  - **LS (Link State) (15 rules)**
  - **OLSR (Optimized Link State Routing) (15 + 19 rules)**
  - **HSLS (Hazy Sighted Link State routing) (15 rules)**
- **Epidemic**
  - **Summary Vector based (17 rules)**

Validation of Declarative MANETs

- Declarative rules for MANETs executed by the **P2** declarative networking system
- Local **cluster** consisting of 8 nodes connected by high-speed network emulating up to 80 MANET nodes
- **Emulate** network dynamics by adding/deleting links during rule execution





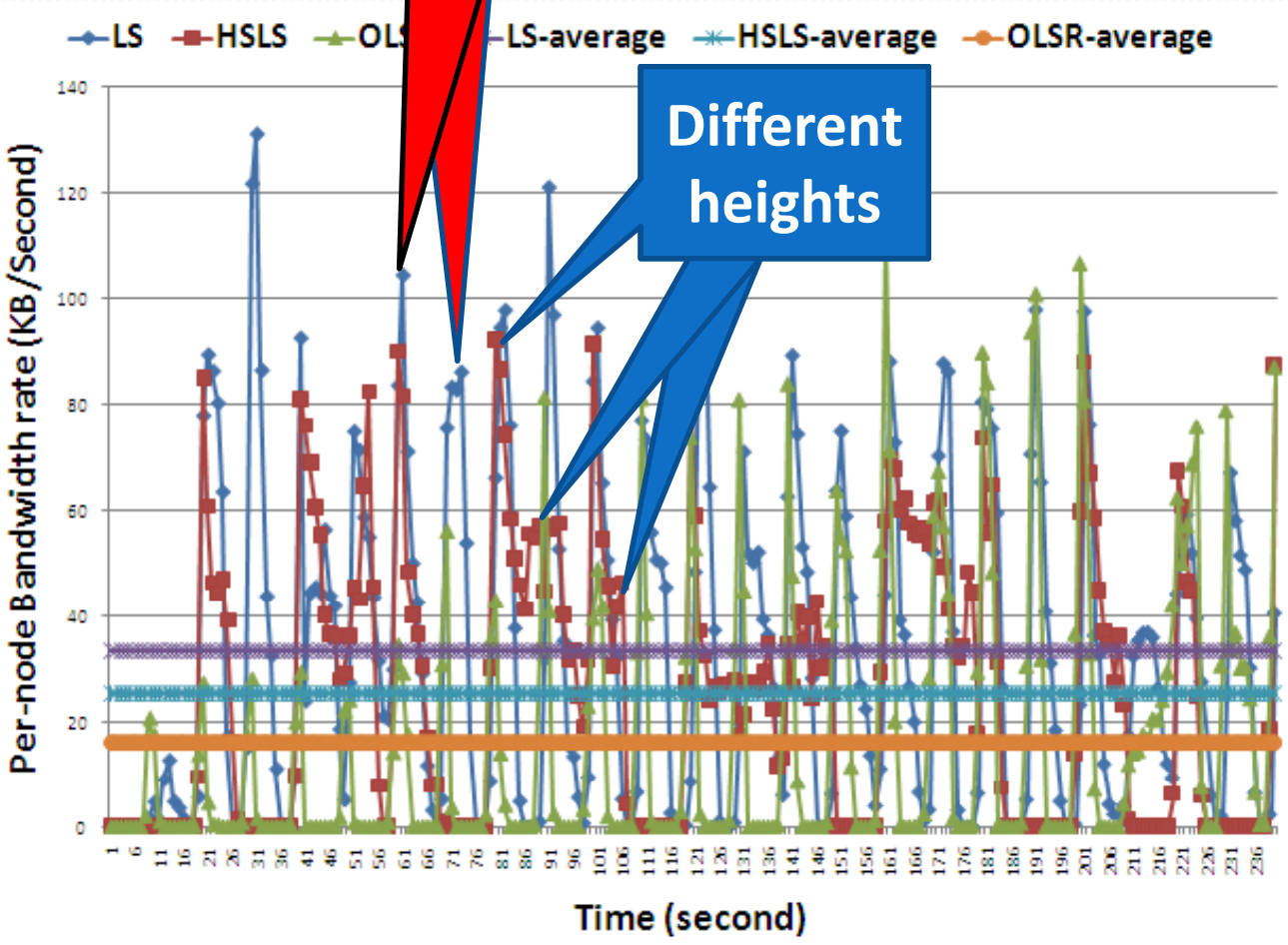
Declarative MANETs exhibit expected scalability trends

Measurements on Real Wireless Testbed

- Orbit wireless testbed at Rutgers University
- 1 GhZ VIA Nehemiah, 64 KB cache 512 MB RAM
- 802.11b ad-hoc mode

ent co-work with **Rick Correa**

23 nodes



Policy-driven Hybrid MANETs

- **Hybrid link-state protocol**
  - HSLS: incurs low bandwidth overhead, scales better
  - LS: quick convergence, may perform better in stable network
  - **AA**: link availability, percentage of time when link is up
  - Based on AA, switch between LS and HSLS

```
#define THRES 0.5
s1 linkAvail(@M,AVG<AA>) :- lsu(@M,S,N,AA,Z,K).
s2 useHSLS(@M) :- linkAvail(@M,AA), AA<THRES.  // unstable
s3 useLS(@M) :- linkAvail(@M,AA), AA>=THRES.   // stable
```

- **Hybrid Proactive-Epidemic**
  - Refer to the paper for more details

• Declarative framework makes it easier to build policy-driven protocol and switch between protocols due to different policies

Component-based Routing

- **Parameterized flood component**
  - (1) What is being flooded (Payload); (2) Which nodes participate (Nbr);
    (3) How far the flooded packet goes (TTL); (4) When flooding is initialized (Sched)

```
flood(@S,Payload,Nbr,TTL,Sched) {
  f1 floodMsg(@S,Payload,Nbr,TTL,Sched) :-      // starting point
     flood(@S,Payload,Nbr,TTL,Sched),Sched(@S,TTL,0,T).
  f2 floodMsg(@N,Payload,Nbr,TTL-1,Sched) :-    // keep on flooding
     floodMsg(@M,Payload,Nbr,TTL,Sched),
     Nbr(@M,N,C),TTL>0,Sched(@M,TTL,T1,T). }
```

- **More:**
  - Customize and reuse component: OLSR flooding
  - Variety of components (neighbor discovery, path computations, etc.) to mix-and-match, e.g. epidemic floods of LSUs

Summary

- Declarative framework makes MANET protocol compact and easy to implement
- Declarative framework allows policy-driven hybrid MANETs and protocol switching to be easily expressed
- Components can be reused among different protocols and to build new protocols

Next Steps

- **Additional evaluations:**
  - Evaluations on Orbit Wireless Testbed and PDAs, and in future, integrate with ns-2/3 simulator
- **Adaptive MANETs:**
  - Implement policy-driven hybrid protocols
  - Component-based routing
- **Protocol reasoning:**
  - Convergence and stability of adaptive MANETs

Thank you

- Q & A