A Declarative Perspective on Adaptive MANET Routing

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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)

“For all nodes S, D: If there is a link from node S to node 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: \( \text{reachable}(S,D) \leftarrow \text{link}(S,D) \)

R2: \( \text{reachable}(S,D) \leftarrow \text{link}(S,Z), \text{reachable}(Z,D) \)

“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: \( \text{link}(\text{source}, \text{destination}) \)
Output: \( \text{reachable}(\text{source}, \text{destination}) \)
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

10 seconds

Different heights

23 nodes

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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

```prolog
#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*)

```prolog
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