Extended ZRP: a Routing Layer Based Service Discovery Protocol for Mobile Ad Hoc Networks

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Outline

- Service Discovery in MANETs
- E-ZRP: Routing Layer based Service Discovery
- Simulation Results
  - Proactive part
  - Reactive part
  - Service Availability
- Conclusions

Service Discovery in MANETs

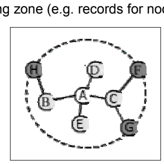
- Service Discovery in fixed networks
  - Assumes reliable communication
  - Mainly centralized approaches
    - (UDDI,Salutation, JINI, SLP, SDP)
- Service Discovery in MANETs
  - Needs to be distributed-decentralized
  - Needs to be scalable
  - Needs to minimize energy consumption
    - (Allia, GSD, DEAPspace, Konark, SANDMAN)
- SANDMAN and DEAPspace
  - power savings only by allowing nodes to go into 'sleep' mode
  - What if continuous connectivity is mandatory?

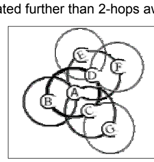
Routing Layer Based Service Discovery: Motivation

- If Service Discovery is implemented **above** the routing layer then
  - **two** message producing processes coexist:
    - one for communicating **service** information among nodes
    - one for communicating **routing** information among nodes
  - hence a node is forced to perform the battery-draining operation of receiving and transmitting packets **multiple times**
- a Routing Layer based Service Discovery protocol: E-ZRP
  - integration of routing with service discovery
    - cross-layer optimization
  - an idea proposed by Koodli and Perkins

Review: Zone Routing Protocol (ZRP) – Haas *et al.*

- combines reactive and proactive routing approaches
- ZRP actually consists of 3 parts:
  - Neighbor Discovery Protocol (NDP)
  - Intra-Zone Routing Protocol (IARP)
    - responsible for proactively maintaining route records for nodes located inside a node's routing zone (e.g. records for nodes located up to 2-hops away)
  - Inter-Zone Routing Protocol (IERP)
    - responsible for reactively creating routes for nodes located outside a node's routing zone (e.g. records for nodes located further than 2-hops away)



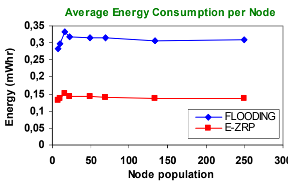


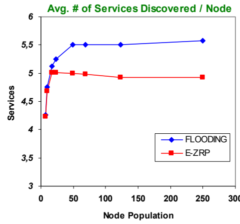
Extended ZRP (E-ZRP)

- Our goal
  - To provide an experimental assessment of energy savings obtained by implementing service discovery at the routing layer
- Our approach
  - select interesting, appropriate MANET routing protocol
  - exploit the capability of acquiring service information along with routing information
  - we modified the Zone Routing Protocol
    - by piggybacking service information into routing messages
    - services are described using UUIDs (Unique Universal Identifiers), in order to keep packet lengths of routing messages small

Simulation Results
Proactive part, Fixed topology

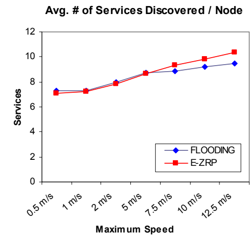
- E-ZRP vs. a traditional Flooding application-layer service discovery protocol
  - Flooding radius equals E-ZRP Zone radius
  - a message in E-ZRP contains info about the sending node's service and also about the services of its intra-zone neighbors
  - a Flooding message contains info only about the sending node's service in order to be shorter
  - same broadcast intervals

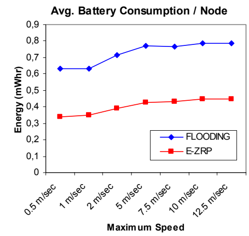




Simulation Results
Proactive part, Mobility

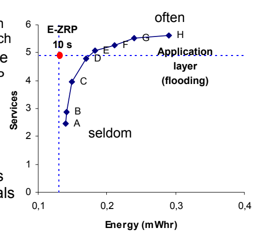
- **random waypoint model** with the following parameters:
  - Min. Speed = 0 (m/s)
  - Pause Time = 30 s.
  - Max. Speed: 0.5 m/s, 1 m/s, 2 m/s, 5 m/s, 7.5 m/s, 10 m/s and 12.5 m/s





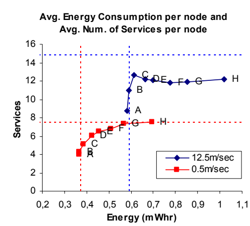
Extended Comparison
Proactive Part

- optimal configuration for application-based service discovery scheme (restricted zone updates)
  - service discoverability is equal to or better than that achieved by a routing layer based approach
- no mobility, 250 nodes, 1000 s simulation time
  - vertical and horizontal blue dotted lines: E-ZRP with a broadcast interval of 10 s
  - Flooding broadcast interval x 4 = Service deletion interval
  - messages are shorter for Flooding than for ZRP/E-ZRP
- Flooding performs better than E-ZRP in terms of service discoverability for broadcast intervals higher than 40 s, but Energy consumption is increased by > 30%
- longer intervals ➜ fewer messages transmitted ➜ nodes receive less services information



Extended Comparison, Proactive part—cont.

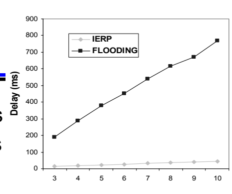
- 250 Nodes, 1000 s simulation time
- **Low Mobility:** min. speed 0 m/s, **max. speed 0,5 m/s** and pause time 30 s
- **High Mobility:** min. speed 0 m/s, **max. speed 12,5 m/s** and pause time 30 s
- **dotted lines**: **E-ZRP** with a broadcast interval of 10 s



	Flooding broadcast interval	Service deletion interval
A	200 s	800 s
B	160 s	640 s
C	80 s	320 s
D	40 s	160 s
E	20 s	80 s
F	15 s	60 s
G	10 s	40 s

application layer based service discovery reaches its optimal performance in terms of energy consumption when the broadcast interval is > 160 s, saving 3% more power but discovering **43%** less services for **low mobility** cases and **22%** less services for **high mobility** cases.

Reactive Part



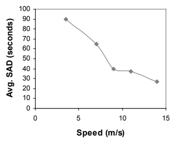
- Flooding imposes significant delays for discovering out of zone services
  - IERP: node needs 10 .. 50 ms
  - Flooding: node needs 200 .. 800 ms
    - Each point on the diagram is an average obtained over 20 service discovery requests between different node pairs @ the same distance
- Since IERP uses the mechanism of bordercasting, it can efficiently and quickly "scan" distant areas of the network to find the requested service
- Flooding takes a long time to "scan" the network since it relies on hop-by-hop broadcasting

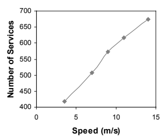
Service Availability

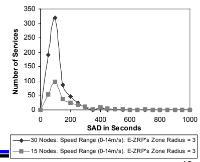
- **Service Availability Duration** (SAD)
  - decreases when speed increases
- Average Transaction Duration (ATD)
  - for a node, for any service
- Tradeoff between
  - average SAD
  - number of discovered services

Service Availability Results

- Average **SAD** actually decreases when speed increases
- **high mobility** (max. speed = 14 m/s): highest # **services discovered**
- **high ATD**: the discovery protocol would perform better **in a low mobility** setting
- **low ATD**: a **high mobility** setting would be ideal for the discovery protocol
- In **high density cases**, the average **SAD is decreased**
  - despite the existence of multiple paths and providers
  - because of higher contention
- The **total number of services discovered** is **higher** in **denser** environments







Conclusions

- E-ZRP leads to significantly smaller energy consumption (approximately 50% less), but also, in certain cases, it achieves higher service discoverability
- 'Favoring' the application layer based service discovery protocol with larger flooding intervals (in order to become more economic in terms of energy consumption (savings of 3%)), had a detrimental effect in service discoverability, reducing it by 22% or more, compared to the proposed routing layer based approach
- Our experiments for out-of-zone services revealed that E-ZRP consumes 5% more energy than Flooding but achieves one order of magnitude smaller delay for discovering services
- We introduced a new metric, Service Availability Duration (**SAD)** for measuring the "quality" of discovered services
  - examined the implications of **network density** and **node mobility** on the availability of services discovered with E-ZRP

Thanks!

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Joint work with my Ph.D. student

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