Performance Evaluation of a Multi-Radio Energy Conservation Scheme for Disruption Tolerant Networks

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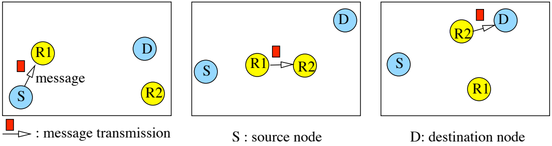
MOBIWAC 2010, Bodrum, Turkey

October 18, 2010

Disruption Tolerant Networks (DTNs)

- Developing network communication when connectivity is intermittent and prone to disruptions
- DTNs differ from traditional networks due to special characteristics
  - Frequent partitions, no end-to-end connection
  - Intermittent connectivity
  - Message delivery delay
  - Limited resources
- Efficient energy conservation schemes are necessary to prolong the network life time



(a) From node S to R1 (b) From node R1 to R2 (c) From node R2 to D

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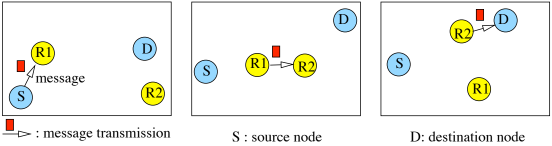

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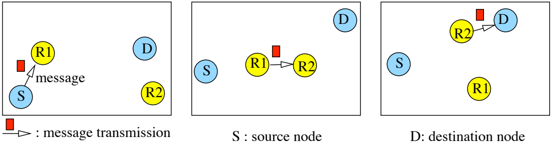

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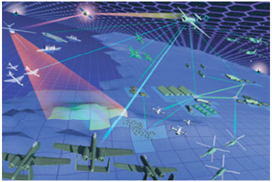
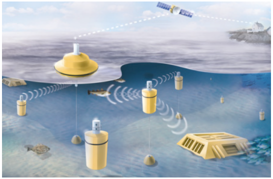
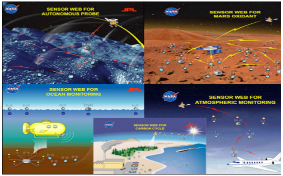
Some Examples/Applications of DTNs







- Military Battlefield Network
- Energy Constrained / Sparse Wireless Sensor Networks
- Underwater Acoustic Networks

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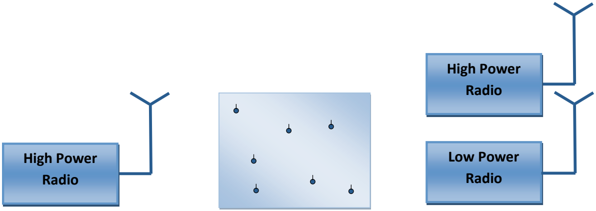
Contribution

Single Radio

- Alternate between sleep mode and active mode to search for contacts and to exchange data

Multi-Radio

- Based only on the low power radio to discover contacts and to awake the high-power
- Based on the high power radio to undertake the data transmission



(Single Radio) (Mobility Models) (Multi-Radio)

Outline

1. Background
   - Mobility Models
   - Power Management of Disruption Tolerant Networks
2. Multi-Radio Power Management Scheme for DTNs
   - Performance Evaluation of the MR Power management Scheme
   - Impact of Different Mobility Models on the MR Power management Scheme
3. Summary, Conclusions and Future Directions

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Mobility Models

Random Waypoint (RWP)

- The most common model used to evaluate routing protocols such as DSR and AODV
- Each node chooses some destination randomly and moves there in different speed

Message Ferry Mobility Model (MF)

- Regular nodes (often static nodes)
- Ferries which move around the deployed area in a deterministic path
  - Collect messages from the regular nodes
  - Deliver messages to their destinations or to other ferries

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Mobility Models

Manhattan Mobility Model

- It uses a grid road topology for the movement in urban areas
- Nodes move in horizontal or vertical streets

ZebraNet Mobility Model

- Zebra Mobility models are based on zebra's movement habit

Human (Orlando) Mobility Model

- The Orlando mobility model is based on actual data gathered from human mobility

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Power Management of DTNs

Oracles and Knowledge-Based Mechanisms

- These power management mechanisms based on knowledge of future contacts
- Assume that nodes have synchronized clocks
- Save 50% of the energy compared to the case when no power management apply

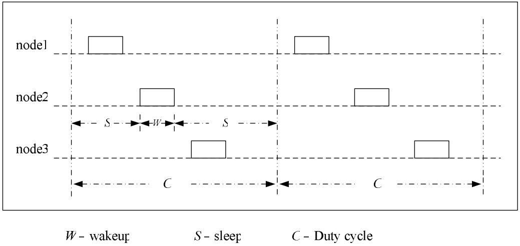
Hierarchical Power Management

- It is based on the previous mechanisms and assumes synchronization among nodes
- Use additional low-power radio to discover contacts and to awake the high-power radio to exchange data
- Saves 73% of the energy compared to the case when no power management apply

Power Management of DTNs

The Context Aware power Management Scheme (CAPM)

- Asynchronous mechanism (each node works on its own wake-up schedule)
- The CAPM scheme has a fixed duty cycle
- Each node wakes up for a fixed or adaptive period and sleeps for the remaining time
- The CAPM achieves 80% energy saving while PSM in Hierarchical power management scheme saves 40%



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Multi-Radio Power Management Scheme for DTNs

Multi-Radio combines concepts of on-demand and asynchronous schemes by using

- Low-power radio (LPR) interface to search for neighbors
- High-power radio (HPR) interface that is woken on-demand to exchange data

Power usage of low and high power radios (in Watt)

Radio	Tx	Rx	Idle	Sleep	Bit Rate
WaveLan	1.3272	0.9670	0.8437	0.0664	2 Mbps
XTend	1	0.36	0.36	0.01	115.2 Kbps

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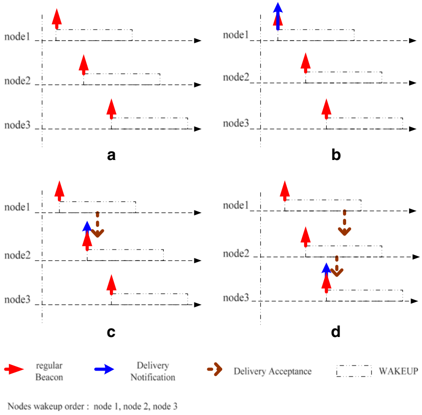
Neighbor Discovery and Data Delivery

- Each node periodically wakes up for a period W in a fixed duty cycle of length C



Multiple possible neighbor discovery scenarios

Simulation Setup

Simulation Scenarios

- Each scenario is set up with 40 nodes, distributed over
  - 1000 x 1000 m^2
  - 1150 x 1150 m^2
  - 1400 x 1400 m^2
  - 2000 x 2000 m^2
  - 3000 x 3000 m^2

Traffic Model

- We use constant bit rate traffic with 10 CBR flows and a packet size of 512 bytes.
- The traffic generation for each flow varied from 0.25 pkts/s to 3 pkts/s.
- Only a maximum of 10 connections are allowed during each run.

Evaluation Metrics

1. **Normalized Energy Consumption (NEC):**
   The ratio of the energy consumption when multi-radio scheme is applied divided by the energy consumption in the absence of energy conservation
2. **Delivery Ratio:**
   The ratio of the number of the successfully received data packets divided by the number of the data packets sent
3. **Average End-to-End Delay:**
   The average delay it takes to deliver a data packet from the source to the destination

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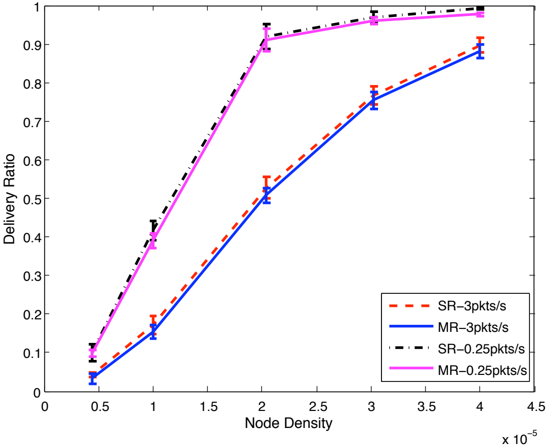
Impact of Node Density on Delivery Ratio of the MR using RWP



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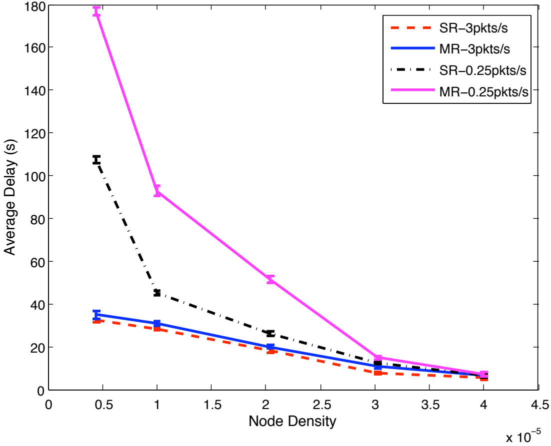

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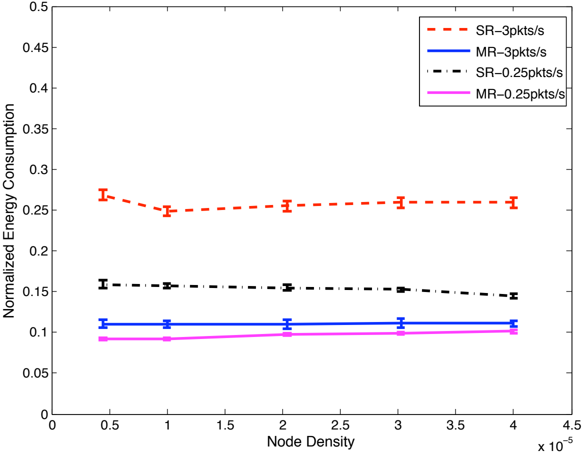
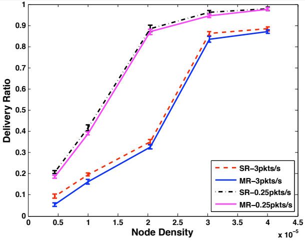


Impact of Varying Node Density and Traffic Load on the Delivery Ratio for Different Mobility Models



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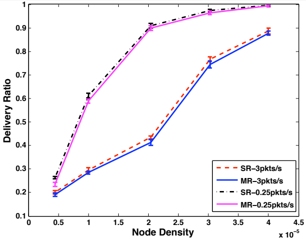

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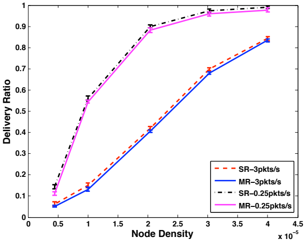

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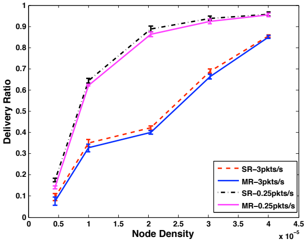

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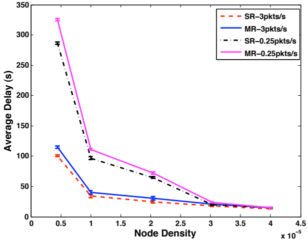

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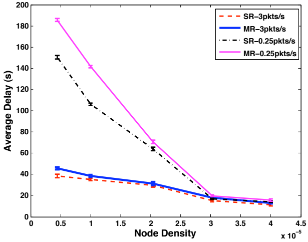

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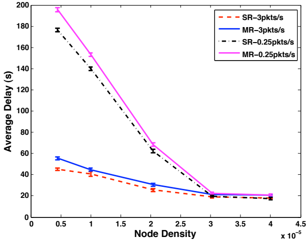

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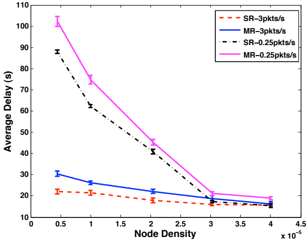

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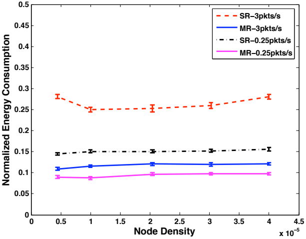

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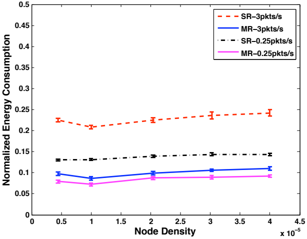

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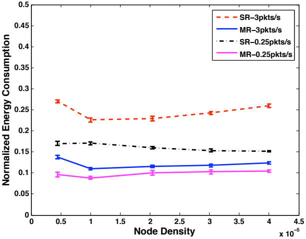

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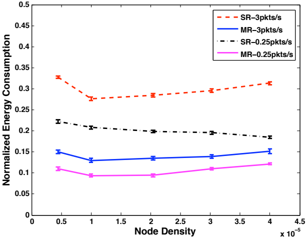

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Summary I

Energy saving of different mobility models at low data rate (0.25 pkt/s)

Mobility Model	SR Eng. Saving	MR Eng. Saving	Delta
RWP	85%	90%	5%
MF	86%	93%	7%
Zebra	85%	91%	6%
Manhattan	84%	89%	5%
Orlando	77%	87%	10%

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Summary II

Energy saving of different mobility models at high data rate (3 pkt/s)

Mobility Model	SR Eng. Saving	MR Eng. Saving	Delta
RWP	73%	88%	15%
MF	76%	90%	14%
Zebra	73%	89%	16%
Manhattan	72%	86%	14%
Orlando	67%	84%	17%

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- The MR uses two complementary radios: a low-power radio for neighbor discovery and a high-power radio to undertake the data transmission
- We evaluated the MR scheme with different mobility models and we compared it with a single radio scheme (CAPM)

Conclusion

- The MR scheme is adaptive to different mobility models
- The MR scheme can achieve almost the same delivery ratio compared to the single radio power management scheme

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Future Directions

Routing Protocols

- It would be interesting to study the behavior of the MR scheme with other routing protocols such as MaxProp

Traffic Models

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Adaptive Radios

- To explore adaptive radios for energy saving techniques in disruption tolerant networks

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THANK YOU

Questions???