

Expending Ring Search Algorithms and Their Energy-Time Efficiency

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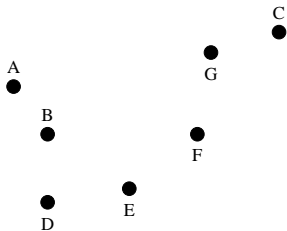
(joint research with Jinguik Kim, Goldsmiths and Yuji Shen, University of Birmingham)

Outline

- 1 Introduction
- 2 Problems of interest
- 3 New measures
- 4 BERS and ERS
- 5 Simulation results
- 6 Conclusion and Discussion

Mobile ad-hoc networks (MANETs)

- A collection of mobile computer devices
- cooperating to *forward* packets for each other
- over a *multihop* wireless network.



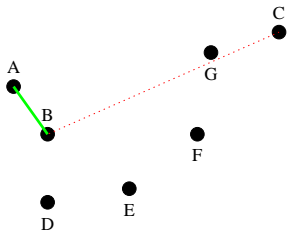
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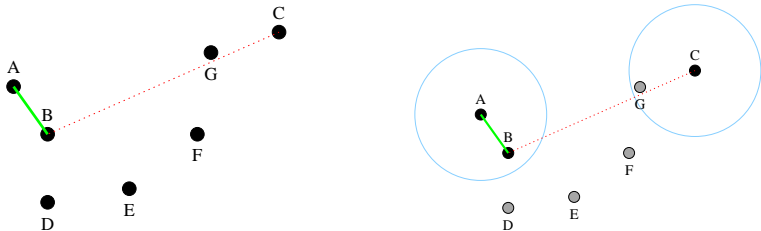
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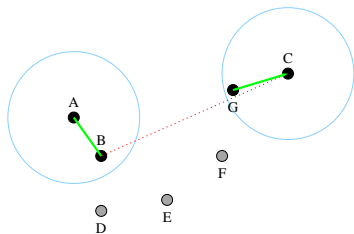
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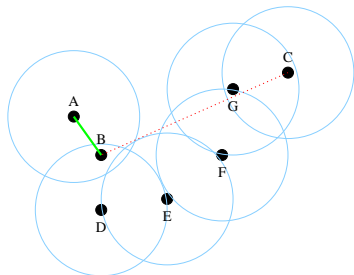
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Model and assumption

To focus on strategic solutions, consider

limit resources e.g. energy power, bandwidth for communication

variable capacity link asymmetric infrastructures

dynamic network topology mobile nodes, movements are independent of each other

transmission

- *one-to-all* model: a packet can reach all one-hop neighbour nodes (nodes within one radius distance)
- *one-to-one* model: a packet is addressed to one neighbour only, using narrow-beam directional antennas or separate frequencies.

source initiated on-demand routing no routing until a source needs to send a message.

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Energy efficiency

Complex and difficult to measure if not impossible

- network interface consumes most energy, which depends on
 - operating mode, e.g. sleep, transmit, receive or idle
 - hardware technology and natural environment
- network layers lead to different energy savings
- many power control techniques, etc.

Problems of interest

Energy efficient routing To *reduce* the total energy consumed in forwarding a packet from the source to destination.

Minimum-energy routing To *minimise* the total energy consumed in forwarding a packet from the source to destination.

Cost and tradeoff The cost for energy saving and the balance between protocol choices.

Example

Comparing

Expanding Ring Search (ERS)

Blocking Expanding Ring Search (BERS)

Which one is better? When is it better? How much better?

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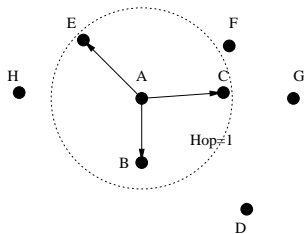
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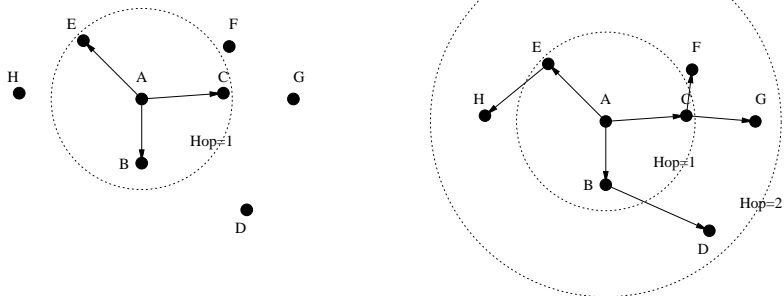
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Expanding Ring Search (ERS)



- The flooding is *controlled* by a pre-defined *Time To Live (TTL)* value.

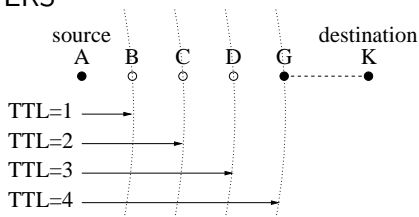
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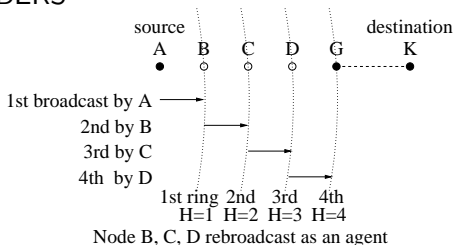
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Example

ERS



BERS



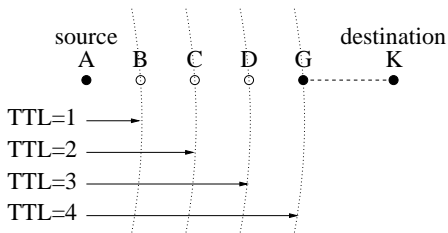
- ① Source node broadcast a RREQ with a hop number $H=1$
- ② Neighbour B receives RREQ with $H=1$, first ring is made
- ③ If no node knows the route to the destination, the node in the first ring rebroadcasts the RREQ with an increased hop number, e.g. $H=2$, and so on, until $H=TTL$.
- ④ The incremental value of TTL is usually 1 or 2.

Energy consumption of ERS and saving of BERS

worst case When TTL runs out, source restarts a new ERS.

cost energy and time

measure in *unit* e.g. the energy consumed for a packet to be delivered from one node to its one hop neighbour.

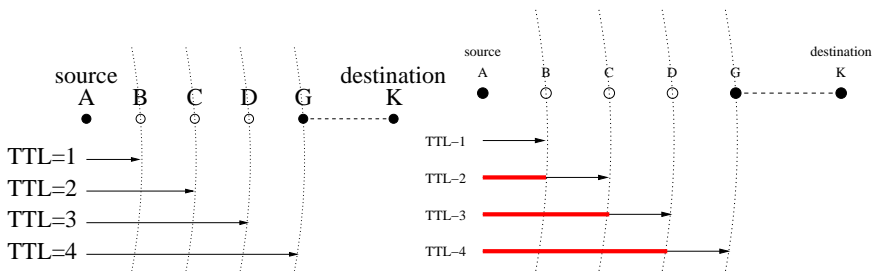


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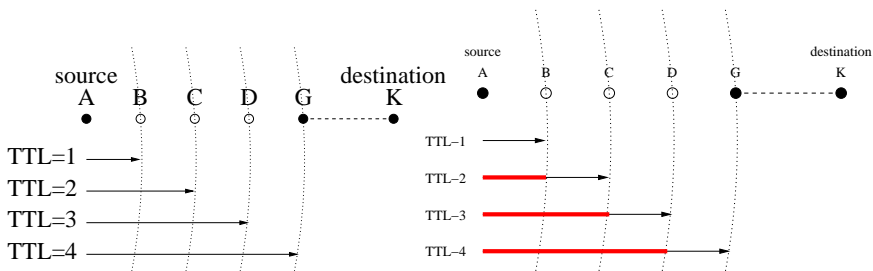


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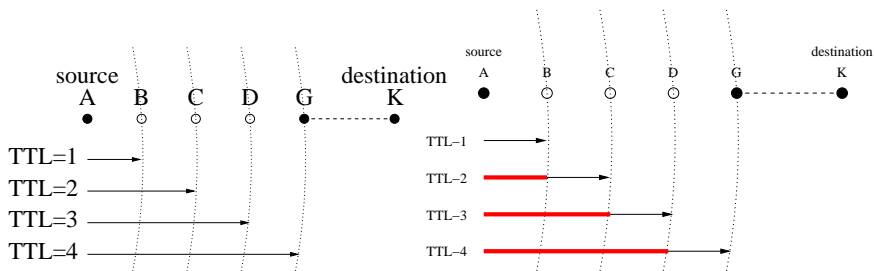


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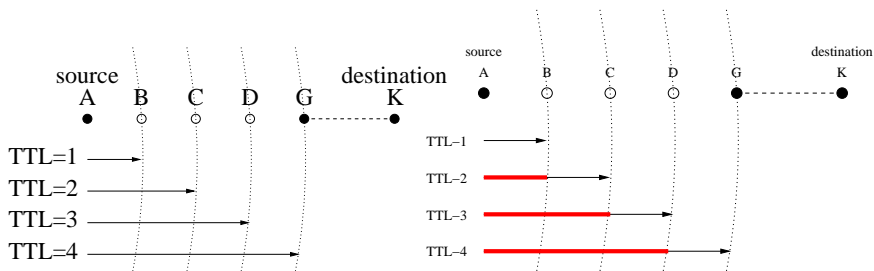


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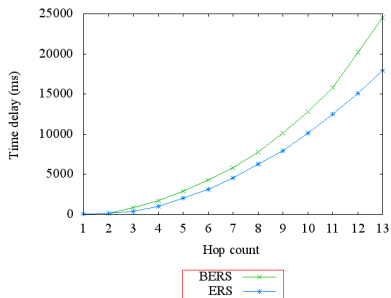
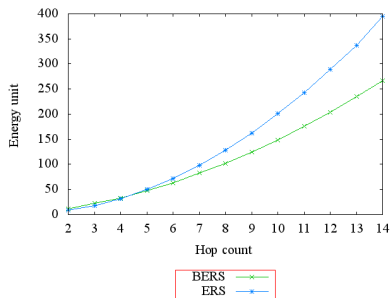
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Energy saving and Time delay

The energy is saved at the *cost* of longer time!



Challenges

The energy consumption of a real MANET can be far more complicated to determine.

- diverse mobile computer devices
- on different operating systems
- under different energy management schemes, yet they need to cooperate to forward packets and to maintain a live network as long as possible.
- either or both time factor and energy constraint in applications

Our goal

- find a combined measure that takes into consideration of both the energy consumption and the time required
- the measure should be
 - scalable
 - genetic
 - simple
 - flexible and
 - capture the energy-time tradeoff nature

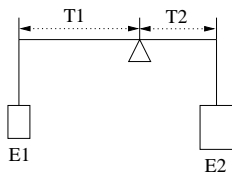
Product model

$$C(n) = E(n)T(n)$$

where n is the size of the input data.

- n is the size of the input data. It is task-oriented, e.g the number of expanding rings, or the number of nodes.
- $E(n)$ is the energy consumed
- $T(n)$ the time it takes to complete a task.
- The cost function $C(n)$ takes two arguments $E(n)$ and $T(n)$.

Moment principle and cases



- 1 If $E_1 = E_2$, then $T_1 = T_2$;
- 2 If $E_1 \neq E_2$, then $T_1 \neq T_2$.

Inbalanced cases

- 1 $E_1 < E_2$ (or $E_1 > E_2$), and $T_1 = T_2$,
this means that Approach A (or B) is more energy efficient than Approach B (or A).
- 2 $E_1 = E_2$, and $T_1 < T_2$ (or $T_1 > T_2$),
this means that Approach A (or B) is more time efficient than Approach B (or A).
- 3 $E_1 < E_2$ (or $E_1 > E_2$), and $T_1 < T_2$ (or $T_1 > T_2$),
this means that Approach A (or B) is more efficient in both of energy and time than Approach B (or A).
- 4 $E_1 < E_2$ ($E_2 < E_1$), and $T_1 > T_2$ (or $T_2 > T_1$),
this means that Approach A (or B) is more energy efficient but not time efficient than Approach B (or A).

General product model

$$C(n) = E(n)T^\alpha(n), \text{ where } \alpha \geq 0$$

- α is a positive real number.
- The general cost function (1) becomes our linear cost function (1) when $\alpha = 1$.

Extended general product model

$$C(\mathbf{E}, \mathbf{T}) = \mathbf{E}^{-1} \mathbf{T}$$

We have the extended general model as follows:

$$C(\mathbf{E}, \mathbf{T}) = \begin{pmatrix} E_1 \\ E_2 \\ \vdots \\ E_m \end{pmatrix} (T_1^\alpha, T_2^\alpha, \dots, T_m^\alpha)$$

Trade model

A normalised measure and is defined as

$\Delta E / \Delta T$, where $\Delta T \neq 0$

$$\frac{\Delta E}{\Delta T} = \frac{E_2 - E_1}{T_1 - T_2}$$

Analytical expression for energy saving

- The total energy consumption by the Blocking-ERS is

$$E_{B-ERS} = 2\left(1 + \sum_{i=1}^{H_r-1} n_i\right) + E_{RREP} \text{ (UnitEnergy)}$$

- Similarly, the total energy consumption by the conventional TTL sequence based ERS is

$$E_{TTL-ERS} = H_r + \sum_{i=1}^{H_r-1} \sum_{j=1}^i n_j + E_{RREP} \text{ (UnitEnergy)}$$

- The difference between the E_{B-ERS} and $E_{TTL-ERS}$ is

$$E_{saved} = H_r - 2 + \sum_{i=1}^{H_r-1} \left(\left(\sum_{j=1}^i n_j \right) - 2n_i \right) \text{ (UnitEnergy)}$$

Analytical expression for time delay

- The formula of the time delay in the Blocking-ERS is given

$$T_{B-ERS} = 3H_r + 2 \sum_{i=1}^{H_r} i \text{ (UnitTime)}$$

- Compare this to the TTL sequence based ERS:

$$T_{TTL-ERS} = 2 \sum_{i=1}^{H_r} i \text{ (UnitTime)}$$

- The time difference between the E_{B-ERS} and $E_{TTL-ERS}$ is

$$3H_r \text{ (UnitTime)}$$

Node distribution

Uniform distribution A total of 1000 nodes are placed uniformly in a geographic area covering a region with H_r of 10.

Pseudo-normal distribution A total of 1000 nodes are within a geographic area covering a region with H_r of 10. For each H_r covered area, 100 nodes are placed uniformly.

Simulation setting

- 1 Under what conditions is BERS superior than ERS in terms of energy-time saving?
- 2 When time is critical, how would the answer to question (i) change?
- 3 When time is not so critical, how would the answer to question (i) differ?

Uniform distribution

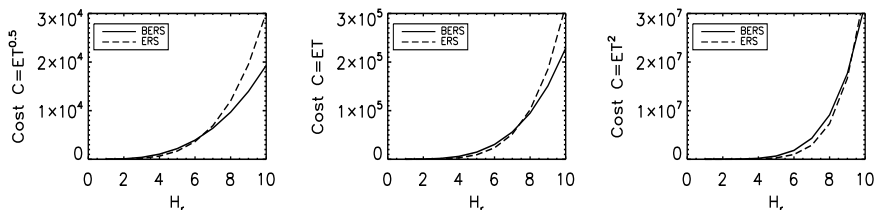


Figure: Energy-time cost from product model when $\alpha = 0.5, 1$ and 2 (from left to right) under uniform distribution.

- 1 When $\alpha = 2$, the two curves have no significant difference
- 2 When $\alpha \leq 1$, the performance of BERS is significantly better than that of ERS when $H_r > 7$.
- 3 It is demonstrated that low weighting should be used for the assessment of energy-time efficiency.

Pseudo-normal distribution

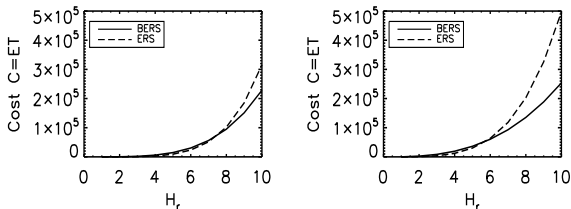


Figure: Energy-time cost from product models when $\alpha = 1$, (left) under uniform distribution and (right) under pseudo-normal distribution.

For the pseudo-normal distribution because there are more nodes in the centre than outside of the centre, there is more energy saving. The good performance for BERS in the pseudo-normal distribution starts at $H_r \geq 6$, while in the uniform distribution which starts at $H_r \geq 7$.

Trade model

This Figure shows the behaviours of BERS in terms of the energy saving traded off by the unit time delay in comparison to that of ERS under two node distributions, namely, uniform distribution and pseudo-normal distribution.

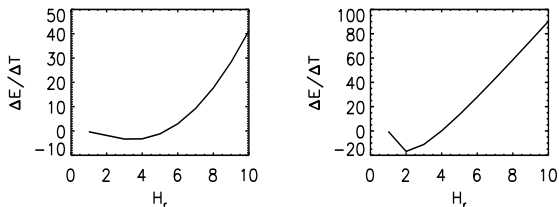


Figure: $\Delta E/\Delta T$ vs H_r : (left) uniform distribution; (right) pseudo-normal distribution.

Conclusion and Discussion

We have

- Introduced two new metrics for assessment of energy-time tradeoffs in MANETs, namely, *cost models* and *trade model*.
- Analysed the the behaviours of the BERS and ERS using of the two models
- Demonstrated the potentials of the approach.

Thank you!

