Age Matters :
Efficient Route Discovery Using Encounter Ages

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Context

FRESH (FResher Encounter SearcH) is an algorithm for *route discovery* in ad hoc networks.

Applicable to protocols which work :

- On demand
- Blindly (no location info, no GPS)

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Design Goals :

- Increase scalability of current routing protocols.
- General algorithm that can be integrated in existing protocols :
  - Not tied to one particular protocol or approach.
  - Can leverage existing work - avoid doing YAP (Yet Another Protocol).

Age Gradient : Make Mobility work for you !

- Mobility Increases Capacity [Grossglauser, Tse Infocom 2001]
- EASE [Grossglauser, Vetterli Infocom 2003] : Scalable location service. Nodes remember *where* and *when* they met other nodes.

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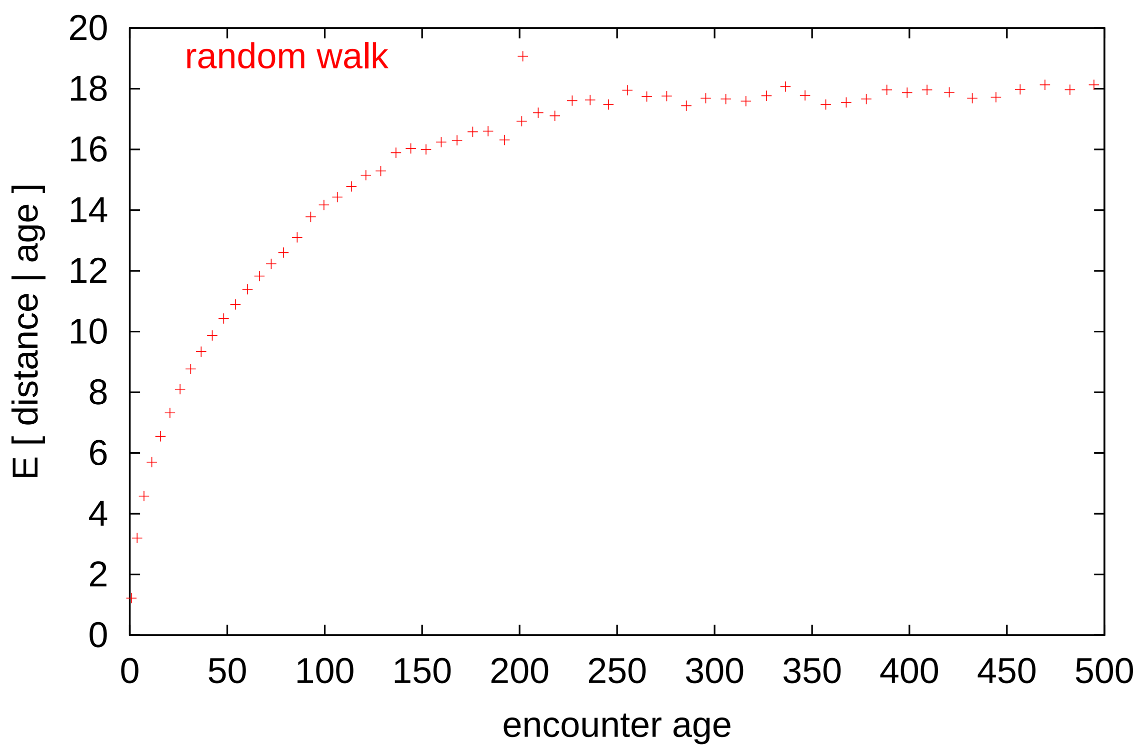
FRESH shows that routing can gain in efficiency even if nodes only remember *when* they met others. This makes use of the *Age Gradient* :

Empirical mean of distance, conditional on the encounter age



Motivation : Scaling Issues

Scaling to larger networks requires to reduce the routing overhead.

- Route discovery inevitably resorts to some form of flooding (global, probabilistic, expanding ring search, etc).
- Flooding is expensive, e.g. :
  Up to 90% of routing overhead in AODV [Das, Perkins, Belding-Royer, Infocom00]

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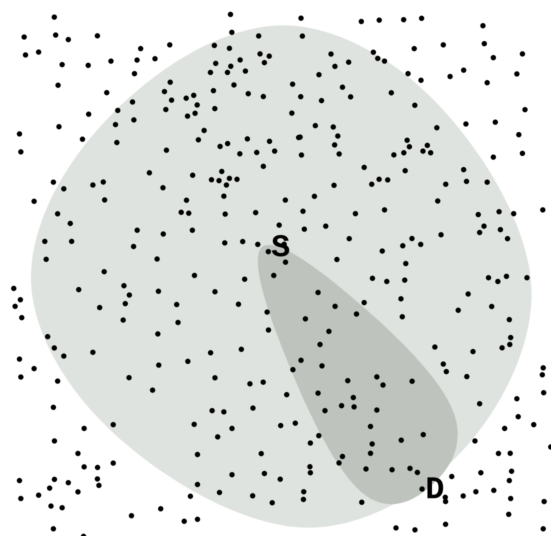
"The fat is in the flood" ... so how do we trim it down ? By restricting the flood to a smaller area and to fewer nodes !



Encounters

Definition : An *Encounter* between two nodes A and B happens when these nodes are one-hop neighbors. (Nodes are one-hop neighbors when within xmit range, without relaying.)

Each node keeps a table of its *last encounter times* with all other nodes.

Encounter table at node S : T_S.

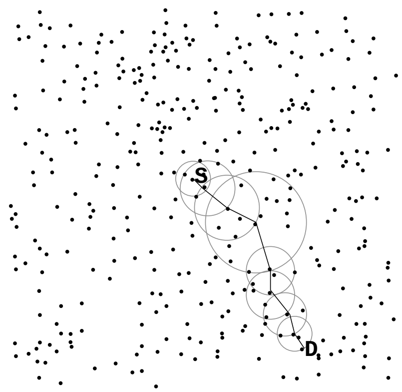
1. $T_S(D)$: time elapsed since S, D were last one-hop neighbors
2. $T_S(D) = \infty$ if S, D were never one-hop neighbors
3. $T_S(S) = 0$

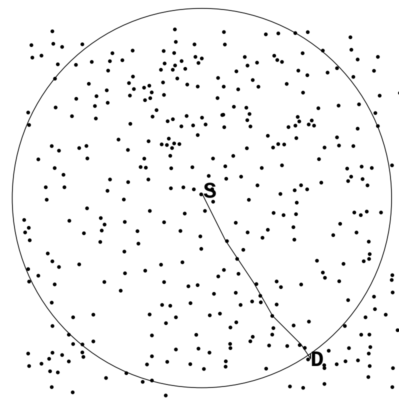
How do nodes "know" when they make encounters ?

1. Overhearing any packet in promiscuous mode
2. "Hello" broadcast messages (Many schemes possible : periodic, adaptive, ..)

Baseline Intuition

1. *Several local searches are cheaper than one global search.*





Therefore, instead of searching for the destination :

Search for any node that is closer to the destination, and repeat from there.

Baseline Intuition

1. *Several local searches are cheaper than one global search.*

Therefore, instead of searching for the destination :

Search for any node that is closer to the destination, and repeat from there.

2. *How to find a node which is closer to the destination ?*

Search for a node which was a neighbor of the destination more recently than myself.

FRESH Algorithm

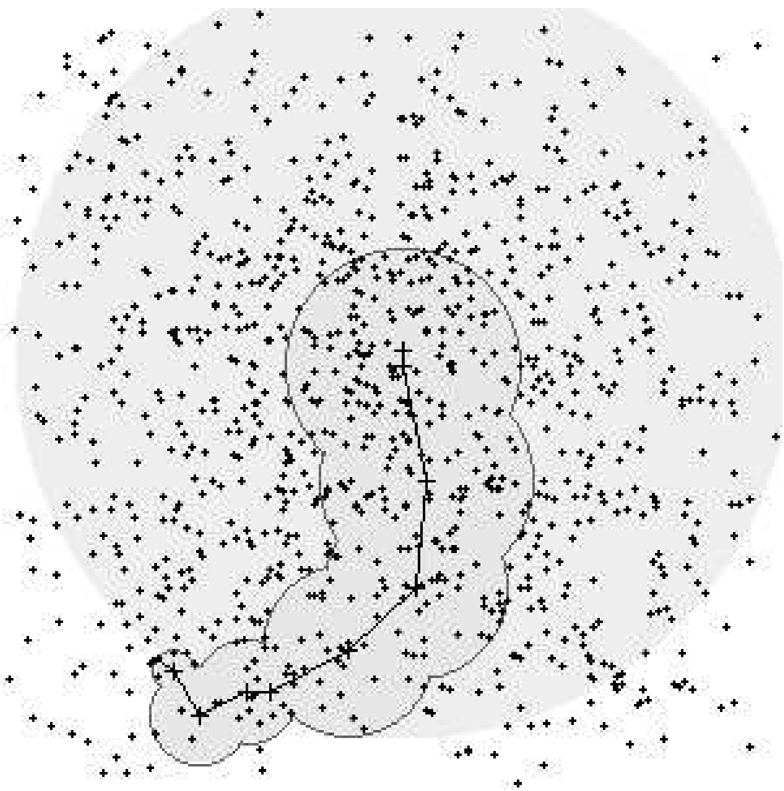
Source S establishes route to destination D :

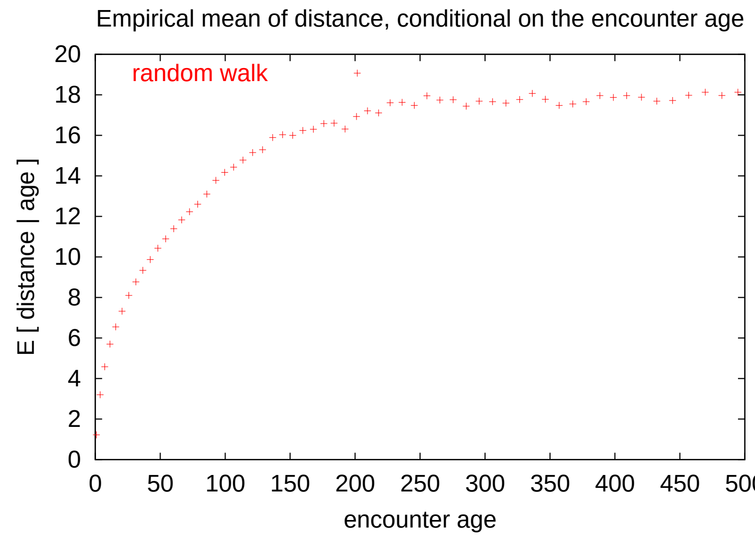
Start at node S.
S floods until reaches a node $A1$ s.t $T_{A1}(D) < T_S(D)$
$A1$ floods until reaches a node $A2$ s.t $T_{A2}(D) < T_{A1}(D)$
$\ldots$
until D is reached (for which $T_D(D) = 0$)

Notes :

1. "Flood until" $\equiv$ some form of expanding ring search.
2. Encounter age decreases at each iteration. Therefore FRESH terminates and is loop-free.
3. Each iteration is equivalent to one route discovery with a standard protocol (AODV, DSR).
4. FRESH works equally well with distance-vector routing as with source-routing.

Example FRESH Route





Source in center, Dest at bottom.

Dark surface : area covered by union of (minimal) fresher encounter searches.

Light surface : area covered by (minimal) direct route discovery search (existing protocols).

Performance Metrics

Route Quality : Ratio of effective route length to optimal route length

Search Cost : Total area flooded (Note : proportional to # pkt xmits, # nodes involved, etc)

Remarks :

1. These two metrics do not go hand in hand !
2. FRESH trades off some route quality in exchange for lower search cost.
3. Route quality vs. search cost weighting depends on session duration.

Simulation Details

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- 64000 nodes
- Square surface, sized to have unit density
- Random walk and waypoint models
- Warmup runs to 40% encounter ratio
- Ideal flooding approximation
- Routes computed sequentially - no cross-traffic.
- Simple MAC Layer

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`mws` (multihop wireless simulator) :

- Design similar to `ns-2/Monarch`.
- Lean and highly efficient, optimized for large-scale simulations.
- Public release expected Fall 2003 ... send email if interested !

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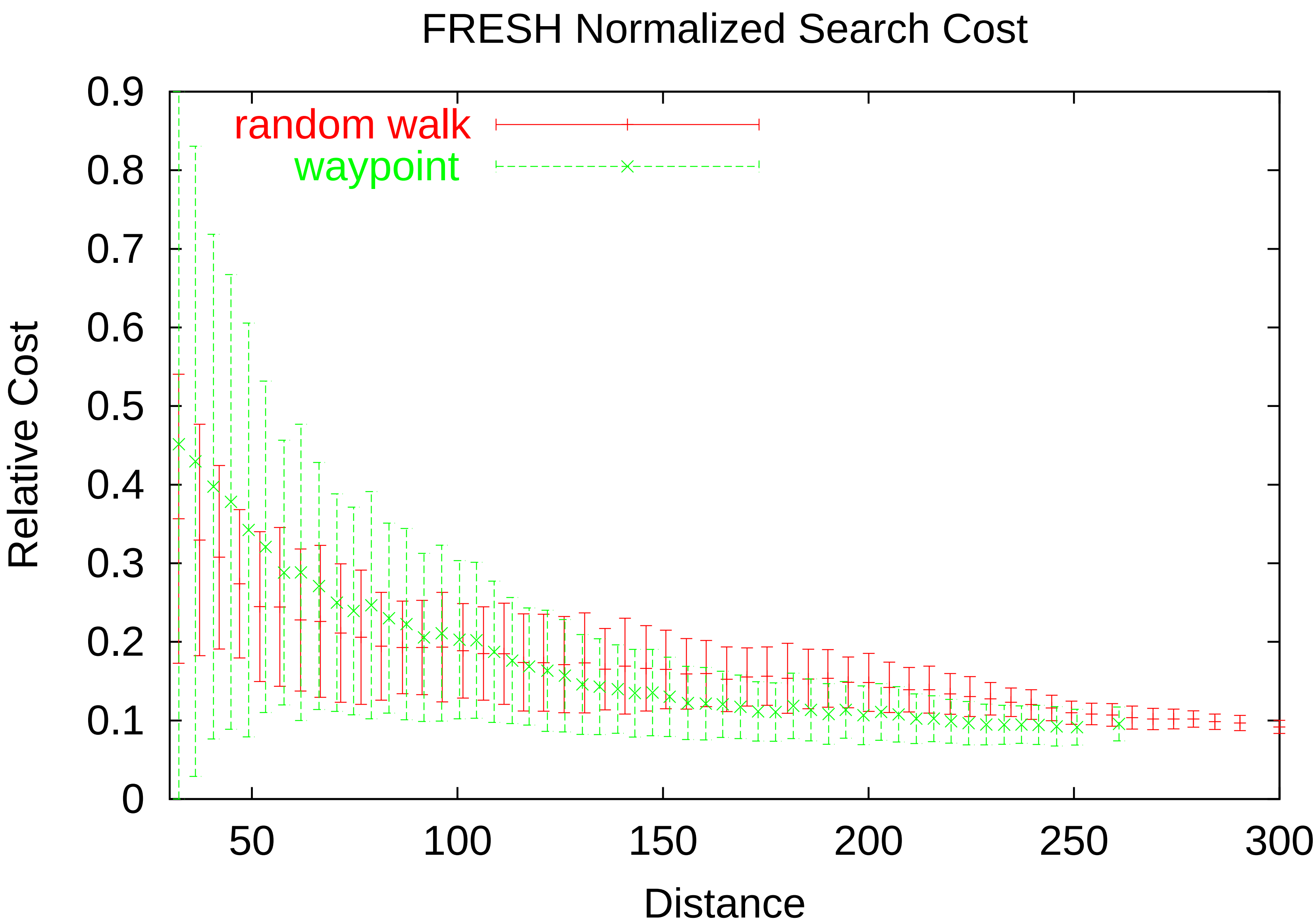
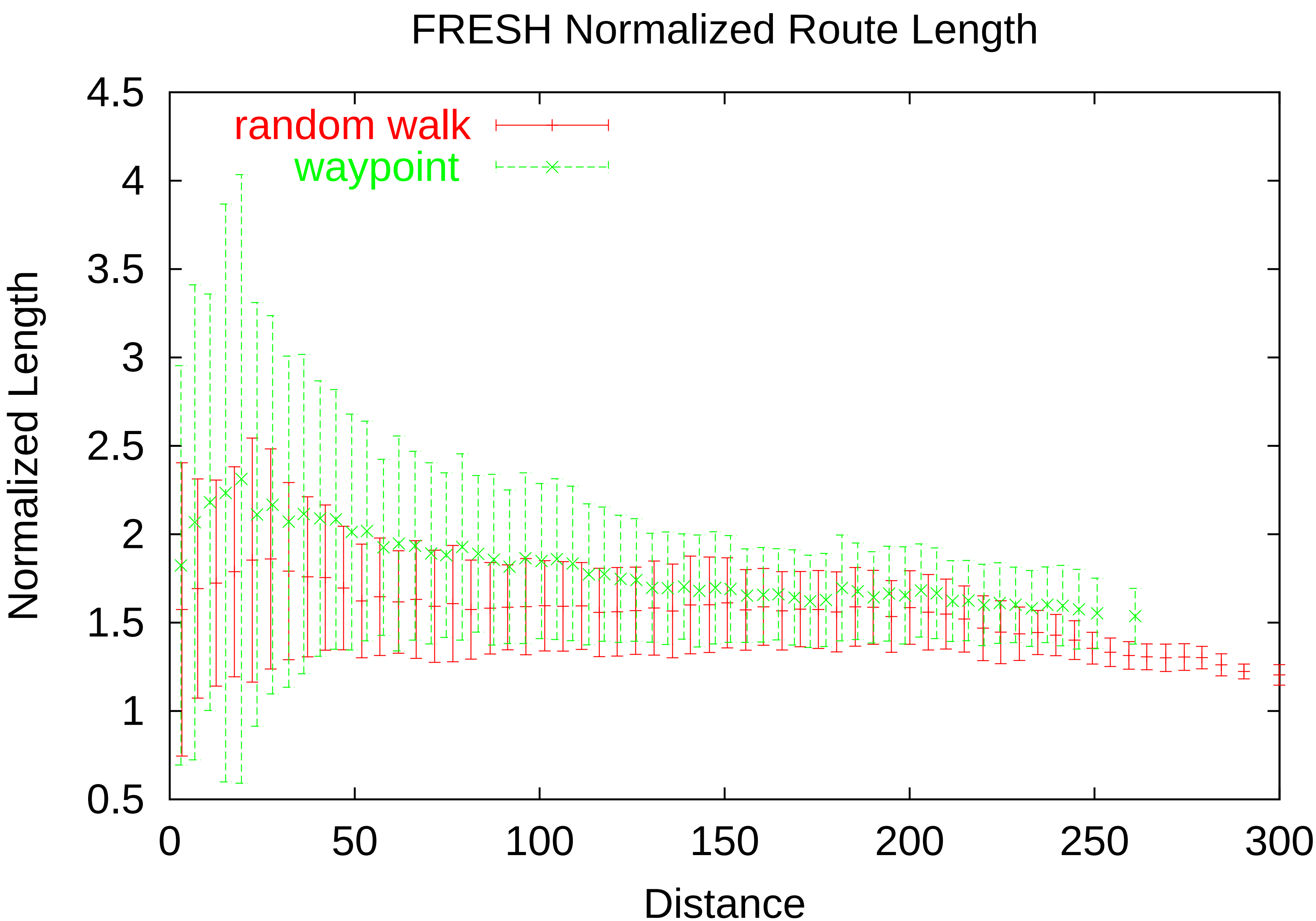
Simulation Results : Search Cost



Simulation Results : Route Quality



Space vs. Time Routing

1. “Traditional” protocols *route through space* :
   Use a *spatial* distance metric (e.g., hops) to advance towards destination.
2. FRESH *routes through time* :
   Use a *temporal* distance metric (last encounter age).

Are both approaches exclusive ? No : Space-Time Routing

- Jointly uses spatial and temporal metrics.
- Parametric algorithm - interpolates anywhere between purely on-demand to purely proactive
- Generalizes FRESH, on-demand distance-vector routing (similar to AODV), and proactive distance-vector routing (similar to DSDV).

Initial results promising.. more details soon !

FRESH - Conclusions

1. Efficient
   - Tenfold gain despite conservative cost metric.
   - Some obvious optimizations will further improve efficiency.
2. General
   - Can be integrated to current protocols (AODV, DSR,..) - leverage existing work !
   - Loop-free
3. Exploits node mobility
   - See EASE [Grossglauser, Vetterli Infocom 2003]
4. Trade off route quality for reduced search cost.
   - Where is the optimal tradeoff ?
   - Can we adjust the tradeoff point based on session duration ?