Many important questions remain unanswered:

- We focus on a delay-tolerant, "intermittently connected" information network in which a terminal communicates only when it is near another.
- Far from an impairment or even a secondary assistant, mobility is indispensable.
- Store-carry-and-forward relaying provides the essential mean of data transfer.
- As an abstraction, we study a simple model in which "random walkers" exchange information when they meet.
- We identify an interesting network architecture, and an available enabling technology.
- Our ongoing study has led to many important questions, and to a few answers.
- In a low-node-density scenario, a mobility-based network is feasible provided that the terminals move over at most 2 dimensions, because then each pair meets infinitely often.
- Many important questions remain unanswered.

**Executive Summary**

<table>
<thead>
<tr>
<th><strong>Random walkers analytical model</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Random walkers" /></td>
</tr>
<tr>
<td>A simple random-walkers model is a useful abstraction (relevant models have been studied [3]).</td>
</tr>
<tr>
<td>A walker hops left or right with equal probability.</td>
</tr>
<tr>
<td>When walkers “meet” they may communicate.</td>
</tr>
<tr>
<td>Static “walkers” may collect and/or help transfer data.</td>
</tr>
<tr>
<td>Model appropriate if terminals do not adjust mobility to facilitate (or frustrate) communication.</td>
</tr>
</tbody>
</table>

**Mobility-based information network**

- In the typical communication network, any pair of "nodes" can talk to each other at any time, at least with the help of intermediate nodes (relaying).
- But such permanent connectivity is not always practical or possible.
- When the application is delay-tolerant, and (some of) the nodes are mobile, an "intermittently connected" network may be practical.
- In such cases, a terminal communicates only when it is near another, mobility is indispensable.
- Sample applications:
  - wildlife monitoring (TurtleNet, ZebraNet) [1]
  - livestock monitoring
  - delay-tolerant human communication (email, short messages, etc) as in Student-Net
  - asynchronous Internet service (India’s Daknet [2])

**Critical low-density question**

- Since terminals need to meet in order to communicate, and obvious concern is: will they meet “often enough” when terminals are “few” (for example, if there are only 2 “walkers”)?
- Since data is generated at perpetuity, they must meet infinitely often.
- Worst case scenario: Do 2 random walkers in a “large” area meet infinitely often?
- Answer: YES, if they “walk” over a 1- or 2-dimensional region. Otherwise, they may never meet (possibly after a finite number of meetings).
- Many application scenarios can be reasonably modelled as 2D or even 1D (corridor, highway, etc).
- But WARNING: a dimension need not be spatial (for example, consider a frequency-hopping system).

**Random walkers analytical model**

- A simple random-walkers model is a useful abstraction (relevant models have been studied [3]).
- A walker hops left or right with equal probability.
- When walkers "meet" they may communicate.
- Static "walkers" may collect and/or help transfer data.
- Model appropriate if terminals do not adjust mobility to facilitate (or frustrate) communication.

**ZebraNet (Princeton U.)**

- power/location-aware sensor net deployed in Kenya.
- selected zebras fitted with a sensing/transmitting collar.
- integrates computing, radio, non-volatile storage, sensors.
- no centralised data collection: while travelling, researchers radio-receive recorded data from zebras.
- enables novel studies of animal migrations and inter-species interactions.

**TurtleNet (U. of Massachusetts)**

- turtles fitted with GPS, solar panel, radio and battery within weight/size limits.
- location, body temp periodically recorded.
- when 2 are within 150m, devices swap data.
- data relaying ends at a single base station.
- device dynamically adapts to energy status.

**Daknet: the electro-mechanical Internet**

- Store-carry-forward (SCF) relaying is indispensable.
- A sends a packet to B, B stores, carries and forwards it to C when B and C are sufficiently close.
- Special-purpose nodes may help:
  - “data mules” may randomly move and collect data from sensors.
  - a “normal” vehicle (such as a taxi or bus) may be a “data mule”.
  - simple static “throw boxes” in strategic locations may aid data exchange.

**More questions than answers**

Many important questions remain unanswered:

- Even with only 3 “walkers”:
  - If A has data for B and meets C, how much data should A transfer to C for C to carry and eventually forward to B (if relaying is “costly”)?
  - By how much does relaying increase “capacity”?
  - If all 3 meet, how should the channel be allocated?
  - Should “broadcasting” be used, and if so, which “gain” would result?
- With more walkers:
  - How to mitigate interference, when 2 pairs meet near each other?
  - How high must “walker density” be to justify “channelisation”?

---

**See our VTC-Fall’09 paper and:**

