Forget him (or her) and keep on moving

... Challenges in opportunistic mobile networks

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Motivation

● In a near future …
  – most of us shall access the Internet using a mobile device
    well, … really?
  – Infrastructure for Index/DNS/TCP
  – Any alternative? …

● In this talk, I argue
  – that it may be a good news after all
    “mobility allows favorable structural properties to emerge.”
  – that it can provide an environment for exciting research!
Structure of the talk

- Motivation
- Challenge: emergence of navigability
- Key: the “move-and-forget” Dynamics
- Why it matters for future mobile social networks

- Concluding remarks
Some wise thoughts from Bordeaux

● “Nul plaisir n’a goust pour moi sans communication …
  (where is the fun if you can’t tell a friend?)
  Montaigne, Essais III-9

● … mais il vaut mieux encore estre seul qu’en compagnie ennuyeuse et inepte.”
  (how boring it is to tell anybody else?)

Maintaining a social network is a delicate human need!
Navigability of augmented graphs

- Goal: shrink distance without even changing routing!
  - Greedy routing in a graph
  - Add a small number of links, used incidentally
    ... such that routing uses $O(\text{polylog } N)$ steps?

- Can augmentation help?
  - a regular tree ...
  - a lattice of any dimensions ...
  - a graph with bounded doubling dimension ...
    ... Yes, any of them!
Warning #1: Navigability ≠ Expander

- Navigability is a tightly related to harmonic distribution
  - Ex.: augmented lattice [Kleinberg00]
  - random independent shortcuts
    density $f(v) \sim (d(u,v))^{-(\alpha)}$
  - $\alpha > 2$: no polylog paths
  - $\alpha = 2$: navigable
  - $\alpha < 2$: no dist. algorithm can route in polylog
Warning #2: Navigability in practice?

- Can navigability be observed, explained, reproduced?
  - Some empirical evidence
    - [LibenNowell05] LiveJournal social network exhibits near-harmonic distribution
  - Can it emerge from local dynamics?
    - [Clauset03][Sandberg07]: search adaptation strategy can approach harmonic distribution
    - Navigability remains open
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Local dynamics

- **H1**: Friends are people we met in the past
  - it requires co-location, face-to-face interaction
  - therefore it emanates/depends on mobility

- **H2**: We forget friends, primarily in function of time
  - a friend requires some maintenance, and there’s 24h in a day.
  - geography is secondary (remote exchange)

“Our friends are the people we met in the past and that we still remember.”
The “Move-and-Forget” model

- Nodes maintain connection with
  - their “local neighbors” (e.g. a grid topology)
  - one “long range contact”, which follows a “move and forget” process

  This long range contact moves according to a random walk
  A long range contact with age $a \geq 0$ is re-initialized with probability $\phi(a)$
Convergence to a steady state.

- The previous model follows an ergodic Markov chains if and only if \( \sum_{j \geq 0} \prod_{i=1}^{j} (1 - \phi(i)) \) is finite.

- The long range contact, as seen in steady state, distribution follows the following density distribution

\[
f(d) = \sum_{a \geq 0} \pi(a) \cdot \Pr\{X(a) = d\}.
\]

- Where \( \pi(a) \) denotes the age stationary distribution
- And \( X(t) \) denotes a random walk started in 0.
Harmonic forgetting ensures navigability

- Let us assume that people forgets harmonically
  - When you have known someone twice longer, you are twice less likely to forget him now.
    \[ \phi(a) \propto \frac{1}{a} \]

- Networks are navigable in steady state.

**Theorem 1** There exist \( d_0 \geq 0 \) and two positive constants \( c \) and \( c' \) such that, for any \( d = (d_1, \ldots, d_k) \in \mathbb{Z}^k \) with \(|d_i| \geq d_0\) for all \( i \in \{1, \ldots, k\} \), we have

\[
\frac{c}{\|d\|^k \cdot \ln^{1+\epsilon}} \leq f(d) \leq \frac{c' \ln^{k/2}}{\|d\|^k \cdot \ln^{1+\epsilon}}
\]

where \( \epsilon > 0 \) is the fixed parameter of M&F, and \( \| \cdot \| \) denotes the \( \ell_\infty \) norm.
A few word on the proof

- Property of the symmetric random walk on a line:
  - For a given $d$, how does $\Pr \{ X(a) = d \}$ depend on $a$?
    - If $a$ is small (less than $d^2$), then it is negligible
    - If $a$ is at least $d^2$, then this probability is roughly $\frac{1}{\sqrt{a}}$
  - This gives, in a $k$-dimensional lattice
    $$f(d) = \sum_{a \geq 0} \Pr \{ X(a) = d \} \pi(a) \geq \sum_{a \geq \frac{3}{4} \|d\|^2} \frac{1}{a^{1+(k/2)}}$$

- The result does not hold for biased random walk
  - Actually, no forget function $\phi$ induces navigable networks.
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What are the **hot** nomadic applications?

- **First generation “the founding fathers”:**
  - interplanetary internet
  - extreme env. (wildlife monitoring, disaster)
  - low-cost Internet service access

- **Second generation “the turbulent teens”**
  - In five years, what will replace the TV ad spot?

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Facebook costs UK employers £30 billion per year! **BBC, 11 sept. 2007**

Typical Facebook user spends 20mn twice per day
In a near future (replay) …

- Users carry handheld devices
  - to store/display content and participate in conversation
  - Infrastructure exist and remains expensive
  - Opportunistic exchanges explode

- Applications addresses content overload
  - Leveraging handmade profiles
    Social networks, locations
  - Activity related newsfeed
    Being notified and being noticed
    Linked with user generated content
Goal:
- locate the nearest item

Revisiting spatial gossip
- Each node maintains mates, replaced by “move and forget”.
- For $\rho \geq 1$, shortcuts as $\frac{1}{d^{\rho \cdot k}}$
- THM: gossiping with mates finds the item using $O(\ln^2 d)$ steps w.h.p. ($d$ is the distance to the nearest item).
Is there (computing) science there?

1. Measuring and understanding human mobility
   - Usually a double edged sword

2. Data mining, Social engineering
   - how to take advantage of contact topology?
   - users’s interest?
   - is it incentive compatible? privacy-hopeless?

3. Experimental/Software platforms
   - Social networking without server, power
Concluding remarks

● Forgetting your friends is socially responsible
  – it’s actually useful.
  – symmetric random walks allows navigability.

● Mobile social networking can exploit navigability
  – making future mobile Internet promising …
  – … and research friendly

● This is just a first step:
  – Other mobility? Get rid of static nodes?
  – long-range contact without infrastructure?
Thank you!