Kinetic Multipoint Relaying: Improvements using Mobility Predictions

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7st International Working Conference on Active and Programmable Network (IWAN'05),

Sophia Antipolis, France, November 21st-23rd, 2005

Outline

Mobility Prediction ?

- Reactive Approach to Mobile Environment.
  - Position Awareness=> Need some kind of geo-localization.
    $\longrightarrow$ GPS for outdoor localization.
    $\longrightarrow$ GPS-free protocols for indoor localization.
  - Piecewise Linear Motion Model.
    - First order model giving a node's velocity.
    - Complex higher order model involving nodes acceleration is possible.
    - Deterministic or Probabilistic.
    - Nodes are assumed to keep a fixed trajectory over a relative short period of time.
  - Trajectory changes are reactively annouced by broadcast messages.

Kinetic Nodal Degree

- Nodes position as a function of time is then described by

$$\mathbf{Pos}_i(t) = \begin{bmatrix} x_i + dx_i & \cdot & t \\ y_i + dy_i & \cdot & t \end{bmatrix},$$

- Node j's trajectory with respect to node i

$$\begin{aligned} D_{ij}^2(t) &= D_{ji}^2(t) = \|\mathbf{Pos}_j(t) - \mathbf{Pos}_i(t)\|_2^2 \\ &= a_{ij}t^2 + b_{ij}t + c_{ij}, \end{aligned}$$

where $a_{ij} \geq 0$, $c_{ij} \geq 0$.

- Solving

$$D_{ij}^2(t) - r^2 \leq 0$$

gives the time intervals t_{ij}^{from} and t_{ij}^{to} during which nodes i and j are neighbors.

Kinetic Nodal Degree (Cont'd)

- Node *i*'s kinetic degree function is

$$Deg_i(t) \quad = \quad \sum_{k=0}^{nbrs_i} \left(\frac{1}{1+\exp(-a\cdot(t-t_k^{from}))} \cdot \frac{1}{1+\exp(a\cdot(t-t_k^{to}))} \right)$$

- the Kinetic Degree is obtained by

$$\widehat{Deg}_i(t) \quad = \quad \int_t^{\infty} \left(\sum_{k=0}^{k=nbrs_i} \left(\frac{1}{1+\exp(-a\cdot(t-t_k^{from}))} \cdot \frac{1}{1+\exp(a\cdot(t-t_k^{to}))} \right) \right)$$

Kinetic Nodal Degree (Cont'd)

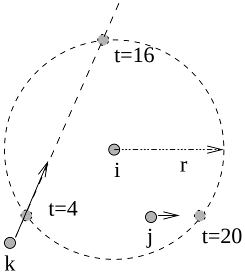

Figure: Node *i* kinetic neighborhood

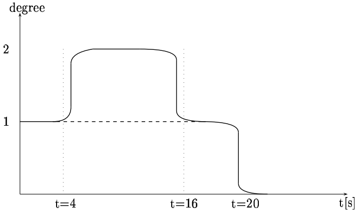

Figure: Node *i* kinetic nodal degree

Kinetic Multipoint Relays

Definition (Covering Interval)

The covering interval is a time interval during which a node in $N^2(i)$ is covered by a node in $N(i)$

Definition (Logical Kinetic Degree)

The logical kinetic degree is the nodal degree obtained when considering covering intervals instead of covering instants

Definition (Activation)

When a node is elected KMPR, it is said to be active and its covering interval is called its activation

Kinetic Multipoint Relays

Kinetic Multipoint Relaying (KMPR)

The KMPR protocol applied to an initiator node i is defined as follows:

- *Begin with an empty KMPR set.*
- *First Step: Compute the logical kinetic degree of each node in $N(i)$.*
- *Second Step: Add in the KMPR set the node in $N(i)$ that has the maximum logical kinetic degree.*
  - *Compute the activation of the KMPR node as the maximum covering interval this node can provide.*
  - *Update all other covering intervals of nodes in $N^2(i)$ and all logical kinetic degrees*
  - *Repeat this step until all nodes in $N^2(i)$ are fully covered*

Simulation environment

- Random Waypoint from the Random Trip Framework [LEBOU:05]
- 20 nodes uniformly distributed in a 1500×300 grid.
- $250m$ transmission range.
- Average Velicity: $10m/s$, $20m/s$, $25m/s$, $30m/s$, $40m/s$.
- Simulation time: $100s$.

Flooding Reduction

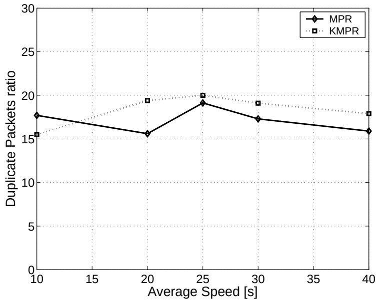

Figure: Duplicate reception

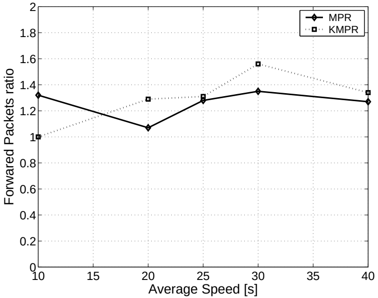

Figure: Forwarding Nodes

Broadcast Efficiency and Routing Overhead

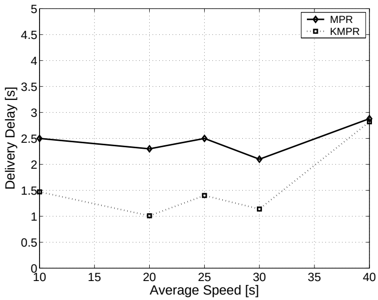

Figure: Broadcast efficiency

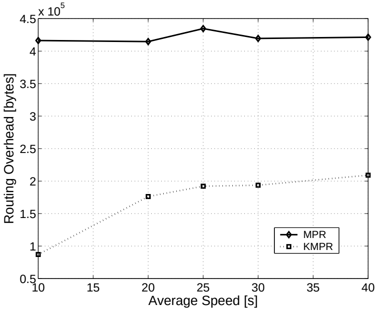

Figure: Routing overhead

Conclusion

- KMPR construct and maintains a MPR set, yet without relying on periodic beacons.
- KMPR has similar flooding properties as MPR.
- KMPR improves MPR broadcast delay by $\approx$ 50 % and MPR channel access by $\approx$ 75 % .

For Further Reading I

- A. Laouiti *et al.*, "Multipoint Relaying: An Efficient Technique for Flooding in Mobile Wireless Networks", *35th Annual Hawaii International Conference on System Sciences (HICSS'2001)*, Hawaii, USA, 2001.
- T. Clausen and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)", `www.ietf.org/rfc/rfc3626.txt`, Project Hipercom, INRIA, France, October 2003.
- Jerome Haerri, Fethi Filali, Christian Bonnet, "On the Application of Mobility Predictions to Multipoint Relaying in MANETs: Kinetic Multipoint Relays", Eurécom Technical Report RR_05_148, Institut Eurécom, France, 2005.

For Further Reading II

Jean-Yves Le Boudec and Milan Vojnovic, "Perfect Simulation and Stationarity of a Class of Mobility Models", In *Proc. of the Infocom'05*, USA, 2005.