# Analysis of a Self-Optimizing Wireless Data Network Using Autonomous Mobile Wireless Routers

**Jaeseok Kim; Liuqing Yang; Jenshan Lin;**
Electrical and computer engineering
University of Florida

**Jonathan Liu**
Computer and Information Science And
Engineering; University of Florida

Radio and Wireless symposium 2006 IEEE

Presented by 康諾

2006/12/29

# OUTLINE

- Introduction
- Network model and simulation set up
- Navigation algorithm
- Simulation Results
- Conclusion

# Introduction(1/3)

- A self-optimizing network capable of reconfiguring itself using mobile wireless routers (MWRs)
- Can be deployed after a natural disaster/ man-made and in battlefields or scientific exploration.

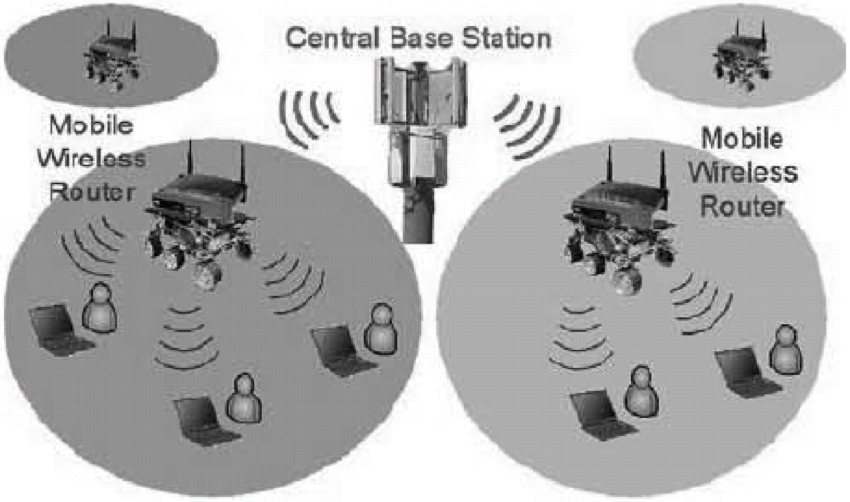



Fig. 1. Concept of the self-optimizing wireless data network with autonomous mobile wireless routers connecting users to a central base station.

# Introduction(2/3)

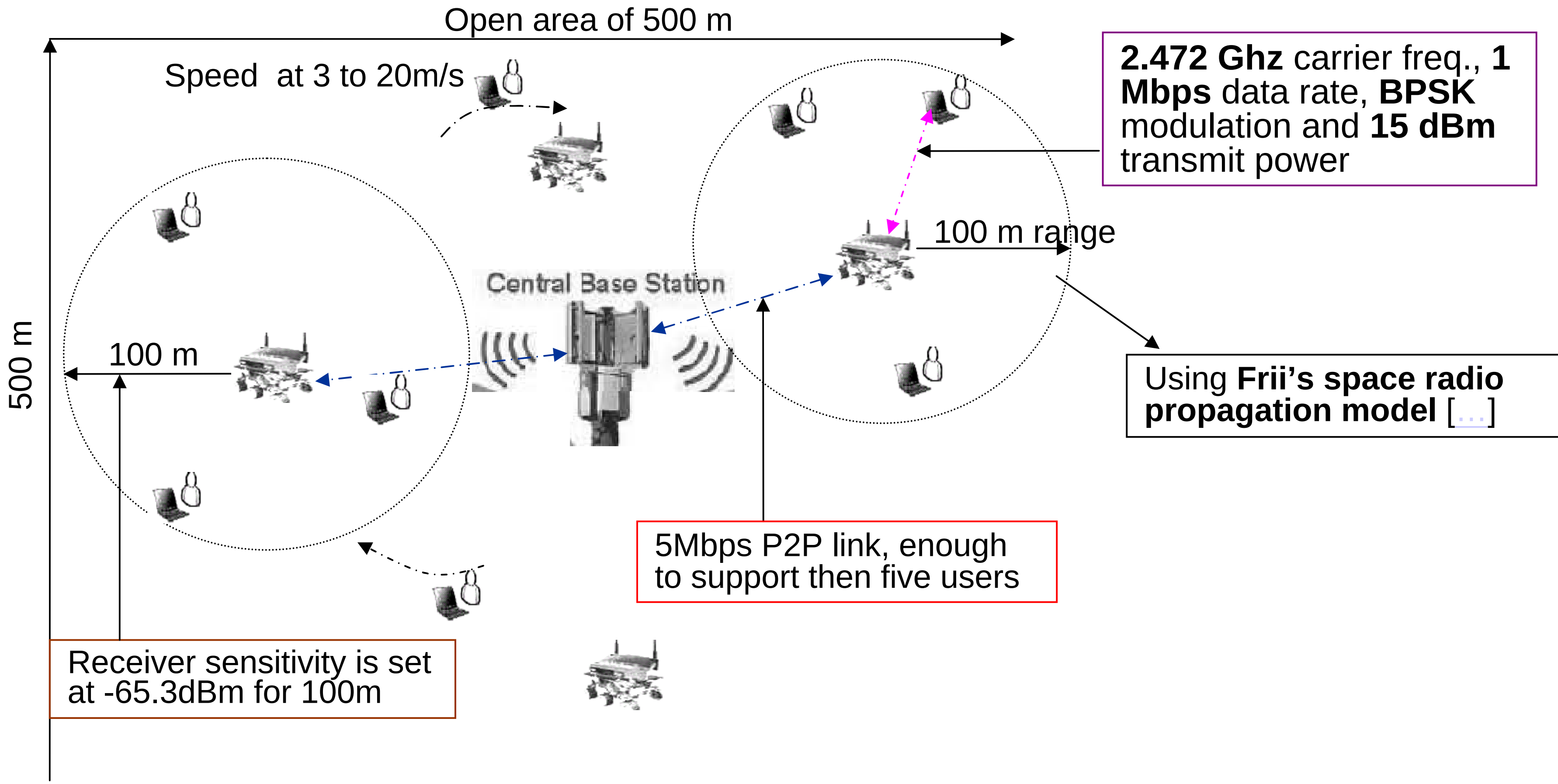
- MWR previous simulations shown better performance than conventional wireless network:
  - larger coverage and lower network outage
- However they were based on voice-based CDMA systems.
- This work is about a wireless data network using mobile wireless routers for an IP-based network.

# Introduction(3/3)

- Immediate goal:
  - Enable the mobility of wireless routers to reduce dropped packets and outage time.
- How?: Using robotic platforms and autonomous navigation algorithm.
- Long-term goal:
  - Use software-configurable PHY layer parameters (antenna, location, frequency, modulation, bandwidth etc) to dynamically optimize network performance.

# Network model and simulation set up(1/3)

- Communication between wireless routers and users is modeled according to IEEE 802.11 standard



# Network model and simulation set up(2/3)

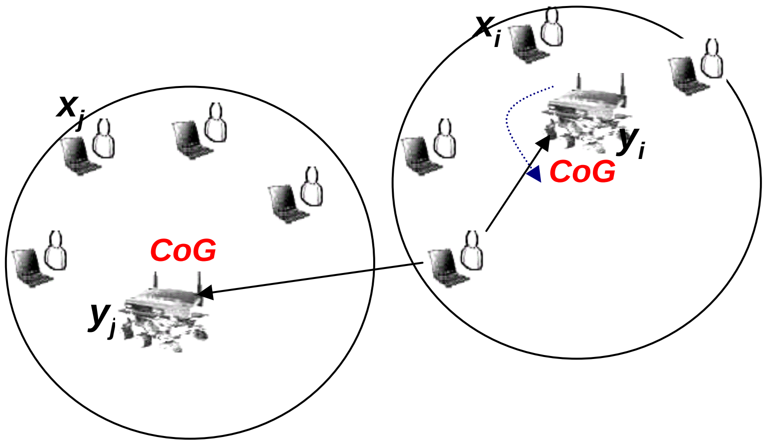
- The antenna model is omni-directional antenna with 0 dBi gain.
- The same configuration is used at both routers and users.
  - wireless LAN PHY layer is symmetrical
- At t=10 s the user start sending data at constant rate (streaming video case).
- At t=250 s, the simulation ends.

# Network model and simulation set up(3/3)

- Three scenarios are simulated and compared:
- Mobile Wireless Routers (MWRs) and fixed users
  - Confirm MWR capability of finding out the optimal topology
- Fixed Wireless Routers (FWRs) and mobile users
  - Conventional wireless for comparison
- Mobile Wireless Routers (MWRs) and mobile users
  - Wireless can reconfigure itself dynamically to match the random distribution of mobile users

# Navigation Algorithm(1/3)

- *Center of Gravity (CoG)*:
  - based on the geometric center of the neighbor mobile users.




$$\mathbf{X}_i = \{\mathbf{x}_{i1}, \cdots, \mathbf{x}_{iN_i}\} = \{\mathbf{x} \mid \|\mathbf{x}-\mathbf{y}_i\| < \|\mathbf{x}-\mathbf{y}_j\|, \forall j \neq i\}$$
$$i, j \in \{1, 2, \cdots, M\},$$

***i*** and ***j*** are indexes of the ***M*** mobile wireless routers.

$N_i$ is the number of the neighbor users to the wireless router $Y_i$

Geometric center : $\hat{\mathbf{y}}_i = avg(\mathbf{X}_i) = \frac{1}{N_i}\sum_{k=1}^{N_i} \mathbf{x}_{ik}$

- Assumption: Use of Global Positioning System (GPS) or network triangulation to locate the users.

# Navigation Algorithm(2/3)

- *Modified Circular Hough Transform (CHT):*
  - Designed to detect the circular shape in a binary image.
  - Modified to find the accurate center of coverage range of a wireless router.

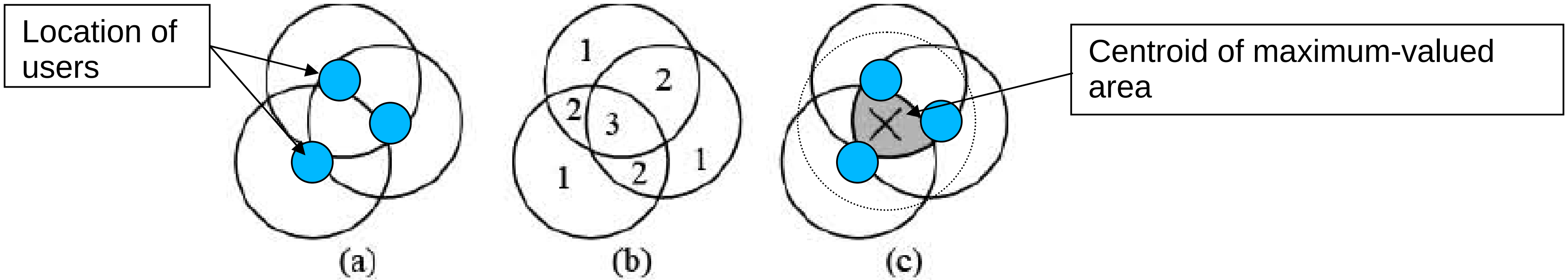



Fig. 2. Modified Circular Hough Transform (CHT)

1. Draw disk centered at the location of users with radius=radio range transmission
2. Value of overlapped area of disk=number of overlapped disks
3. Get the centroid of the maximum-valued area

# Navigation Algorithm(3/3)

- *Trajectory Prediction:*
  - helps to improve the navigation algorithm for fast-moving users.

The linear predictor equation is: $\hat{\mathbf{x}}_i^{(p)}(t) = p \times (\mathbf{x}_i(t) - \mathbf{x}_i(t-1)) + \mathbf{x}_i(t).$

- *p* is the prediction parameter at time *t.*
- $\hat{\mathbf{x}}_i^{(p)}(t)$ can replace the current location of the *i*-th user at time *t*, $X_i(t)$.
- *p* is the trade-off between current location and the predicted one, when *p=0*, $\hat{\mathbf{x}}_i^{(p)}(t)$ = current location
- $\hat{\mathbf{x}}_i^{(p)}(t)$ *is* less accurate to indicate the current location when *p* increases *(*long-term behavior*)*

# Simulation Results(1/7)

- Use of Network simulator *ns*-2 and the model describes in the network setup.
- *CHT* and *CoG* are used independently incorporating *Trajectory prediction* in each case
- For the three following simulations:
  - *CoG* is used by mobile wireless routers
  - Y-axis represents the data packets number from 1 to 80, normalized from 0 to 1.
  - X-axis denotes time from 0 to 250 s
  - The black dots =transmitted packets
  - The white cross mark = the dropped packets

# Simulation results(2/7)

- First scenario: all packets have been transmitted to the central base station without outage

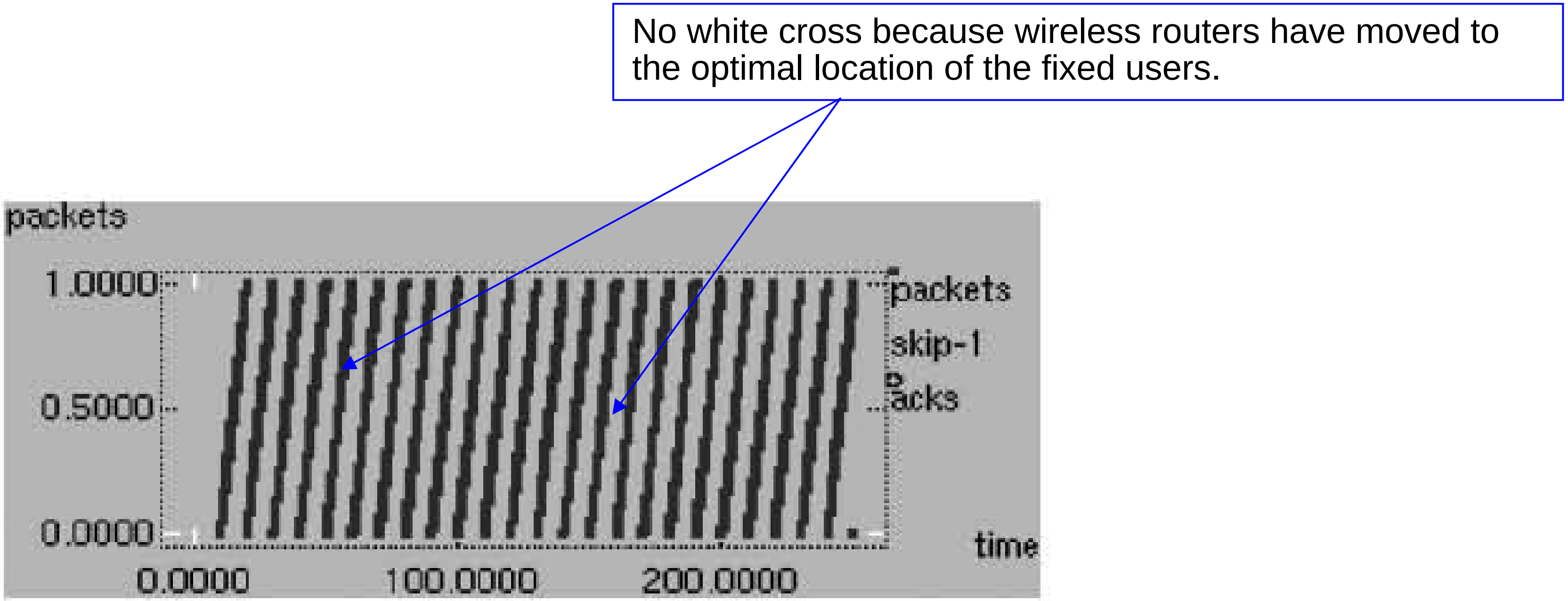



Fig. 3. Simulation of packet data with Mobile Wireless Routers (MWR) and fixed users

# Simulation results(3/7)

- Second scenario: Outage occurs and packets are dropped.

white crosses are observed because users, moving randomly around fixed wireless routers, can get out of range

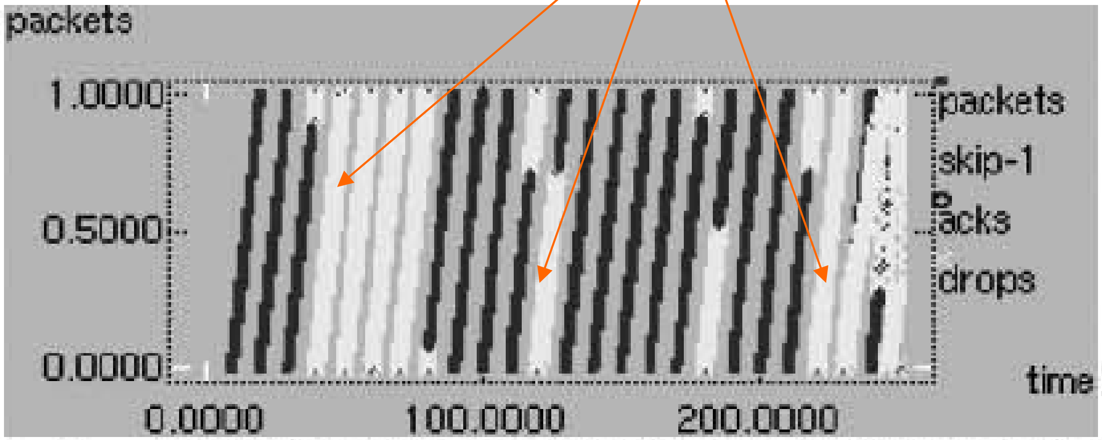



Fig. 4. Simulation of packet data with Fixed Wireless Routers (FWR) and mobile users

# Simulation results(4/7)

- Third scenario:Dropped packets and outage time are reduced compared to the previous simulation.

Few white crosses observed, because the MWRs are moving too.

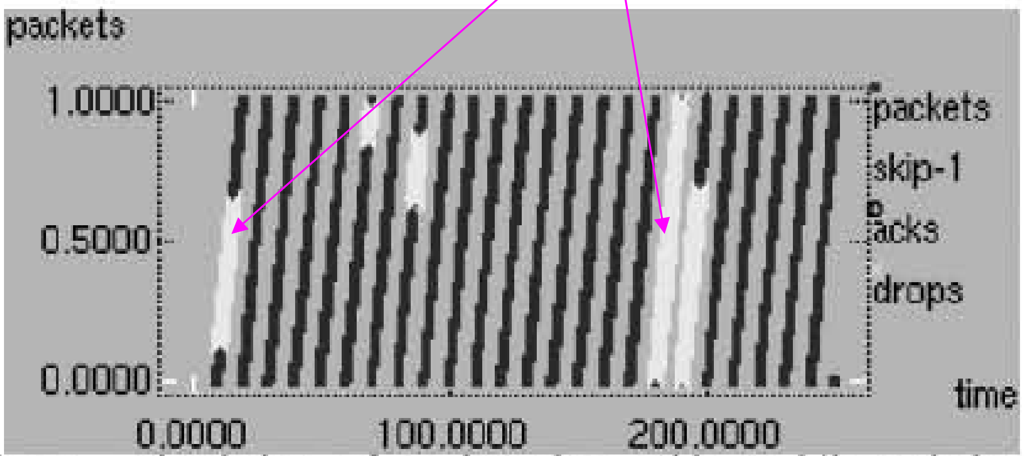



Fig. 5. Simulation of packet data with Mobile Wireless Routers (MWR) and mobile users

  - MWRs are moving to optimize users location based on *CoG.*

# Simulation Results(5/7)

- The table below sums up the difference between the second and third scenario.
- This proves the effectiveness of the navigation algorithm and the proposed network model.

Comparison of Network Performance Using FWR and MWR

| Scenario | Outage | Packets | |
|---|---|---|---|
| | | Dropped | Transmitted |
| Fixed Wireless Router (FWR) | 50.2% | 7662 | 19208 |
| Mobile Wireless Router (MWR) | 30.3% | 4768 | 19208 |
| Improvement | 40% ↓ | 38% ↓ | N/A |

# Simulation results(6/7)

- The next simulation shows the effectiveness of the *trajectory prediction*
- Recall linear prediction: $\hat{\mathbf{x}}_i^{(p)}(t) = p \times \left(\mathbf{x}_i(t) - \mathbf{x}_i(t-1)\right) + \mathbf{x}_i(t).$

About 40% dropped packets reduction when routers speed=mobile users speed with prediction

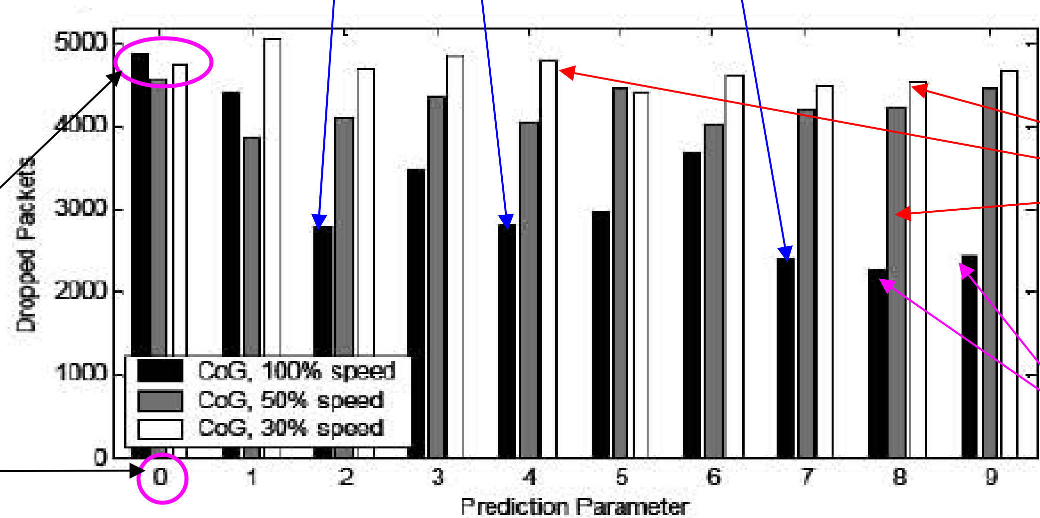



Fig. 6. Effect of Trajectory Prediction on Center of Gravity (CoG)

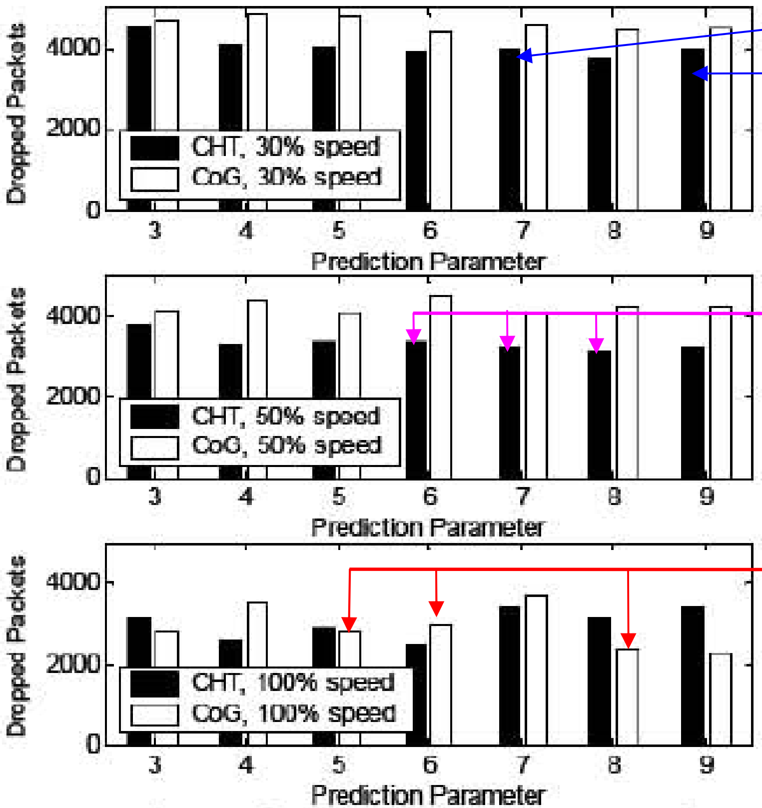
No significant effect when MWRs speed is slower to catch up with mobile users

Large prediction parameter cannot reduce the number of dropped packets

**No prediction** has high dropped packets peaks even when the routers have equal speed as mobile users

# Simulation results(7/7)

- The following simulation compares the effectiveness of *CoG* and *CHT* on the trajectory prediction when the MWRs are slower:




*CHT* performs better than *CoG* because less sensitive to mobile users going in or out of the neighborhood of the slow router

*CHT* get its best performance when the router is half speed than mobile user. Enhancing at the same time the prediction effect.

When mobile users speed=router speed, *CoG* performs better than *CHT* because the router can easily move back to the right track.

# Conclusion

- The self-optimizing wireless using mobile routers improves the network performance.
- Incorporating trajectory prediction with *CoG*, reduces the number of dropped packets by around 40%, especially when routers have same speed than users.
- As energy constraint may slower routers the modified *CHT* replacing the *CoG* provides 30% of reduction.
- There is also a reduction in the number of routers used to cover large area.
- This design is only deployable in limited space
- It will be interesting to integrate Base station mobility in the scenarios.

# Frii's free space radio propagation

- The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver.
- H. T. Friis presented the following equation to calculate the received signal power in free space at distance *d* from the transmitter.

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

  - Where *Pt* is the transmitted signal power. *Gt* and *Gr* are the antenna gains of the transmitter and the receiver respectively.
  - *L(L>=1)* is the system loss, and $\lambda$ is the wavelength. It is common to select *Gt=Gr=1*and *L=1* in *ns* simulations.
- The free space model basically represents the communication range as a circle around the transmitter. If a receiver is within the circle, it receives all packets. Otherwise, it loses all packets
- Source http://www.isi.edu/~weiye/pub/propagation_ns.pdf

Back