A Hybrid Network Model for Cellular Wireless Packet Data Networks

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GLOBECOM 2002

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Outline

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  - An algorithm for the hybrid network model
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Introduction

- Peer-to-peer network model in cellular system
  - Ad hoc network model in wireless networks
- By using peer-to-peer communication
  - Increasing throughput [1]
  - Reducing transmission power [2]
  - Enhancing network capacity [3]
  - Better load balancing [4]
  - Extending coverage area [5]

Introduction (cont.)

- Three critical drawbacks when using peer-to-peer communications in cellular packet data networks:
  - Impact of traffic locality [8]
  - Fairness problem[7]
  - Impact of mobility [6]
    - Network partition
    - Route failures and re-computations

The hybrid network model

- The paper present a hybrid network model called "*Sphinx*"
  - For the optimal use of the cellular and peer-to-peer network models in tandem
- The cellular network supports dual mode
  - Cellular mode (with base station)
  - Peer-to-peer mode (initial state)
- When to switch to cellular mode?
  - Topology constraint
  - Mobility
  - Peer-to-peer throughput lower than a threshold

Variables used in the hybrid model algorithm

n → number of flows in the network
SF → set of flows currently operated in cellular mode
cT → time division allocation for cellular mode
rp → cellular mode repetition period
mp → throughput monitoring period
up → division update period
$Tp(i)$ → route partition timer (timeout=pp) for flow i
$Ts(i)$ → cellular mode sojourn timer (timeout=sp) for flow i
$M(i)$ → mode of operation {CELLULAR, PEER} for flow i
$P(i)$ → peer-to-peer mode connectivity {PARTITION, CONNECT} for flow i
$g(i)$ → throughput over mp for flow i
$G(i)$ → aggregate throughput for flow i
$R(i)$ → reference throughput for flow i

Algorithm of the hybrid network model

At Mobile Station i

Every rp time:

1 participate in cellular mode for cT period

2 participate in peer-to-peer mode for the remaining period

Every mp time:

3 if $M(i)$ is PEER and $g(i) < R(i)$ and $G(i) < R(i)$

4 send **request**[i, JOIN] to the base-station

5 elseif $M(i)$ is CELLULAR and $G(i) > R(i)$ and $P(i)$ is CONNECT

6 send **request**[i, LEAVE] to the base-station

Selective Dequeue:

7 in cellular mode

8 if $M(i)$ is CELLULAR

9 dequeue only packets belonging to flow i

10 else do not dequeue any packets

11 in peer-to-peer mode

12 if $M(i)$ is PEER

13 dequeue head-of-line packets

14 else dequeue only packets *not* belonging to flow i

Algorithm of the hybrid network model (cont.)

```
    Receive division[time t, set S]:
15      cT ← t
16      if i ∈ S
17          M(i) ← CELLULAR
18          start Ts(i) if not set
19      else
20          M(i) ← PEER
21          stop Ts(i) if set
    Callback from routing protocol with reason r:
22      if r is ROUTE-ERROR
23          start Tp(i) if not set
24      elseif r is ROUTE-OKAY
25          P(i) ← CONNECT
26          stop Tp(i) if set
27          if M(i) is CELLULAR and Ts(i) expired
28              send request[i, LEAVE] to base-station
    When partition timer Tp(i) expires:
29      P(i) ← PARTITION
30      if M(i) is PEER
31          send request[i, JOIN] to base-station
32      else  start route probes until P(i) is CONNECT
    When sojourn timer Ts(i) expires:
33      if P(i) is CONNECT
34          send request[i, LEAVE] to base-station
```

Algorithm of the hybrid network model (cont.)

At Base-Station

Every rp time:

35 participate in cellular mode for cT period

Every up time:

36 $cT \leftarrow rp * \frac{|SF|}{n}$

37 broadcast **division**[cT, SF] to mobile stations

Receive **request**[mobile station i, action a]:

38 if a is `JOIN`

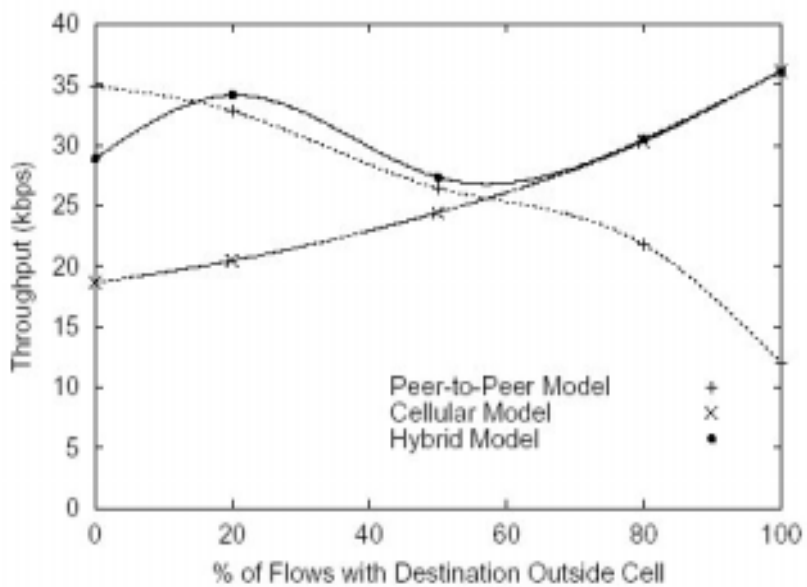
39 $SF \leftarrow SF + \{i\}$

40 else $SF \leftarrow SF - \{i\}$

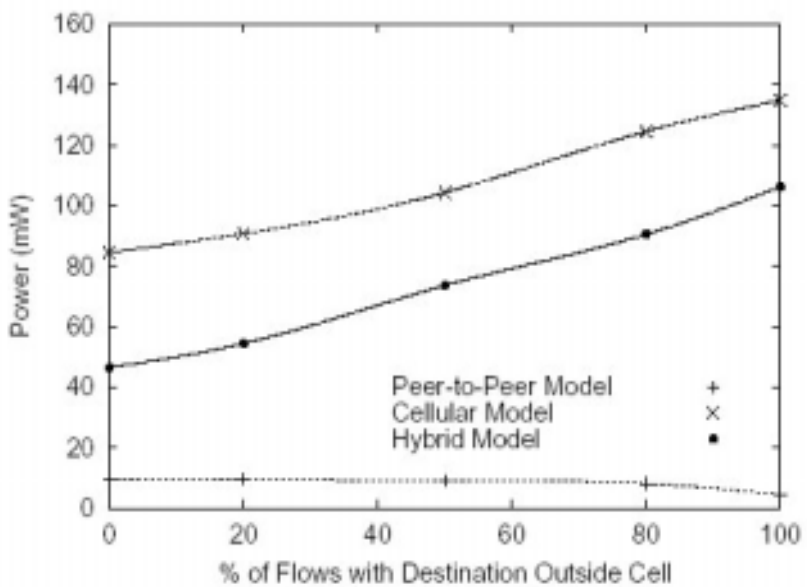
Simulation results

- Simulation model
  - Topology:
    - 100 nodes randomly distributed in a $(1500m)^2$ grid
  - Physical layer:
    - Free space propagation model ($\frac{1}{r^2}$)
    - Two-ray ground reflection model($\frac{1}{r^4}$)
  - Medium Access and routing layers:
    - Similar to IEEE 802.11 MAC protocol in PCF and DCF mode
    - Using DSR(Dynamic Source Routing) in peer-to-peer mode

Impact of traffic locality

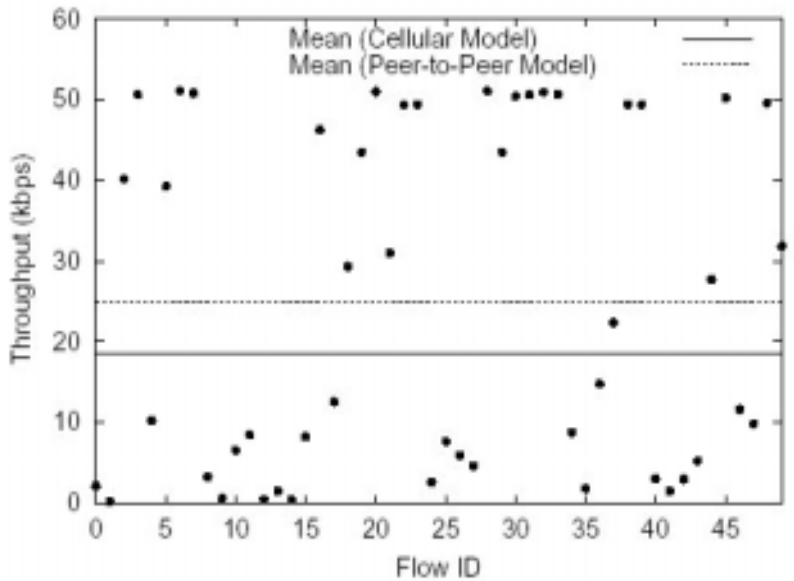


(a) Throughput

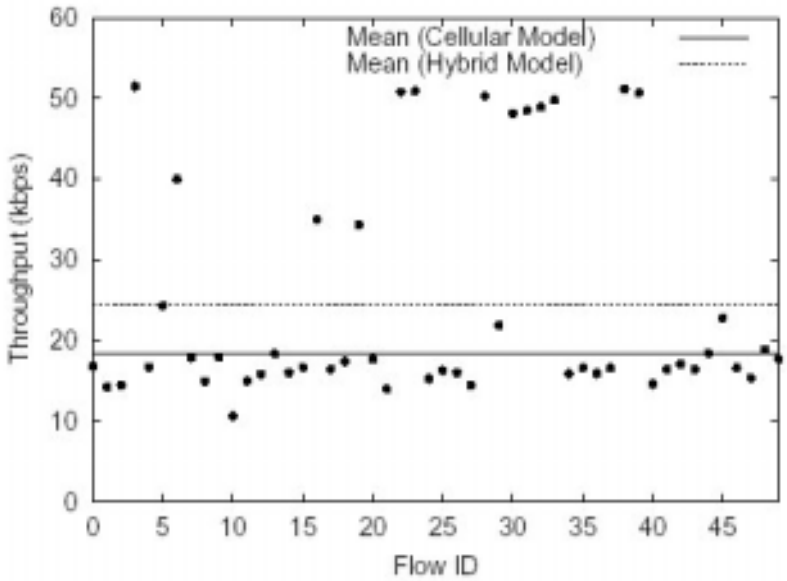


(b) Power Consumption

Throughput distribution

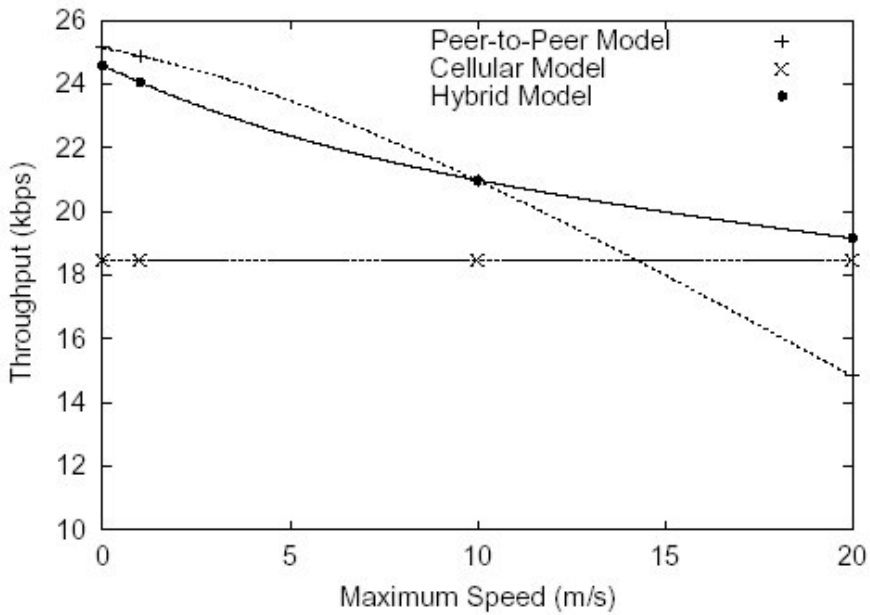


(a) Peer-to-Peer Model

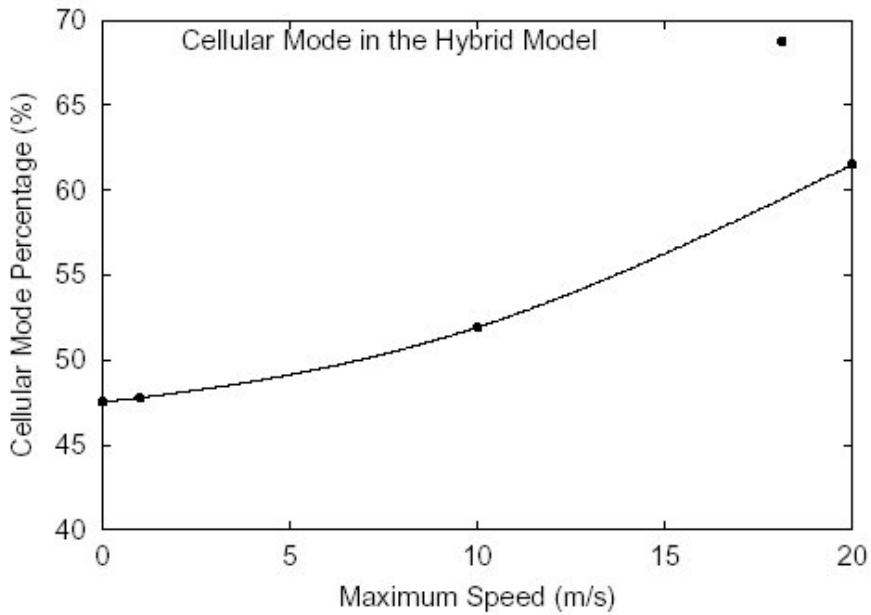


(b) Hybrid Model

Impact of mobility



(a) Throughput



(b) Mode of Operation

Design issues and discussions

- Throughput monitoring
  - Performed in source or destination?
- Base-station centric vs. mobile station centric
  - Additional overheads on MS?
- Multiple channels
- Comparing to WLAN scenario
  - BS (or AP) coverage vs. MH coverage

Conclusion

- The paper present a hybrid network model called "*Sphinx*"
  - Comparing to cellular network
    - Higher throughput
    - Lower power consumption
  - Comparing to peer-to-peer network
    - Better fairness
    - More resilience to mobility and traffic locality

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