Stretchable Architectures for Next Generation Cellular Networks

Presented By
Shashidhar Lakkavalli, Ansuya Negi and Dr. Suresh Singh
Portland State University
Relaying

Source

Relay

Relay

Relay

Destination
Path loss reduction with Relaying

\[ L(\text{in dB}) = 128.1 + 37.6 \log(d) \]

‘d’ = single hop distance in km

\[ L(\text{Cumulative in Watts}) = \text{hops} \times L(\text{in Watts}) \]
Relaying

- Multi-hop connection between source and destination
- Advantages
  - Longer battery life for the source mobile
  - Lower Node and System power
  - Increased capacity of cell
  - Higher system throughput (Energy per bit reduces)
  - Improves coverage in dead spots
    - path diversity
  - Propagation conditions can vary hop by hop.
3G Issues

- Battery power utilized for benefit of others
- Mobile-to-Mobile communication
- Interference at relay’s receiver
- Absence of diversity gain at the relay
- Security
- Handoffs between mobiles in multi-hop
- Power Control between relay and MT
- QOS & Overhead
  - 3G standards shelves multi-hop protocol ODMA due to excessive overhead from signaling.
Our Proposal – Stretched Connection

• Stretched Connection
  – AIM: To increase battery life of a Mobile Terminal using relaying in 3G systems.
  – Scenario: 2 hop relaying
    • Suitable for real time applications with less jitter.
    • Requires a “simple handoff/routing algorithm”
    • Appreciable “energy savings”.
    • Relay: A device with abundant power reserve – cars, full charged MTs
    • Relay is called “intermediary”
    • Relayed connection is called “stretched connection”
Stretched Connection
Soft Handoff

M - Mobile
A - Active Set
N - Neighbor Set

BS1

BS2

M  A  N
1,1 1 2

M  A  N
2,3 1,2 1,3

M  A  N
1,2 2 1,3

M  A  N
1,2 1,3 1,3

M  A  N
1,2 1,3 1,3
Intermediary Initiated Soft Handoff (1)

- Handoff is initiated by intermediaries and assisted by BS.
- BS assist candidate intermediaries by passing location of MT, system parameters of the mobile.
- Relays listen promiscuously to MT’s transmissions, assuming some changes to uplink (ODMA specifications).
- Relays maintain 3 sets - active, neighbor and candidate sets of MTs in its vicinity: similar to Soft Handoff mechanism.
- BS selects the best intermediary.
- Note: For multihop scenario, BS cannot choose all the intermediaries – not scalable.
  - Use of adhoc networking protocol, with metric being SIR at the intermediary.
Intermediary Initiated Soft Handoff (2)

In1, In2 – Intermediaries
M - Mobile
Advantages of Intermediary Initiated Soft Handoff

• Receiver centric
  – The intermediary knows about its “Interference temperature” better than the sender.

• Neighbor discovery and maintenance is done at intermediary
  – Reduced overhead for the MT.

• (MT need not know the identity of the intermediary)
  – Signals from 2 intermediaries is considered as multipath
  – During intermediary soft handoff, MT’s parameters for the connection remain unchanged – unlike soft handoff
FSM of Node in Simulation

- IDLE
  - callInitiation
  - carryCallRequest
  - setIntermediary

- REQUESTED
  - callInitiation
  - startDirectCall

- CARRYING
  - setIntermediary

- DIRECT
  - changeIntermediary
  - stopStretchedCall

- STRETCHED
  - changeIntermediary
Simulation Setup

• Discrete Event simulation
  – Recursive path loss formula for Pedestrian and vehicular radio channel in a Manhattan type terrain (UMTS 30.03 Selection Procedures)
  – Block size = 20 meters
  – Frequency = 1.9Ghz
  – Poisson call arrival (Call rate = 1.2 per hour)
  – All nodes moving with velocity 1.5m/s
  – Stretched connection pathloss is always less than direct connection.
Terrain Map

Probabilities and Velocities
East = 0.3, 1.5
West = 0.3, -1.5
North = 0.4, 1.5
South = 0.0, 0.0
Experimental Setup

- Metrics chosen: Energy, # of handoffs, Time spent in relaying
- Factors chosen: Number of nodes and location of BS
- 1000 sec per run, with 10 repetitions
- Mean and 90% confidence interval plotted
- Diversity gain only between Intermediary and BS
- Pair-wise comparison between stretched and direct connections
- Selection of intermediary based on greedy method
Energy for BS at center
Energy for BS at Corner

Comparison of Always Direct System and Stretched System Energy
(BS corner, call gain = 10)
Handoff

Comparison of handoffs per node to maintain lowest energy (BS center, gain = 10)

- Call rate = 1
- Call rate = 2

Number of Handoffs

Number of Nodes
Time spent in stretched connection by MT
Related Work

• ODMA & Intelligent Relaying: Multihop relaying
• Integrated Cellular & Ad hoc Relaying Systems (iCAR)
  – Relay stations at strategic locations
  – To enable rerouting of congested traffic
  – Increase capacity
  – Uses 802.11 between MTs and relays, and cellular between relays and BS
• Mobility Increases the Capacity of Ad hoc Wireless Networks.
  – Multi-user diversity: Relays “carry” traffic from source to destination.
  – Non-real time applications
  – 2 hop
  – Advantage: O(1) throughput, independent of number of users.
Conclusions

• A 2-hop stretched connection yield significant power savings between 3X – 7X!!!!
• The amount of time spent in relaying is 10-15% of idle time – not a significant overhead!!!!
• Handoffs increase linearly with number of nodes
  – Intermediary initiated handoff reduces overhead for MT.
  – No overhead of ad-hoc networking protocol for 2-hop stretched connection.
• 2-hop stretched connection suitable for real time applications
Future Work

• Implementing intermediary based soft handoff.
• Capacity and throughput analysis.
• Developing optimizations to choose the best intermediaries