Future Work

- Integration with Mobile-IP
- Integration with IP multicast
- Integration with AIRMAIL
- Using location information from level 1 to improve level 2 handoff

Conclusions

- Very fast local handoff is possible (3-5 ms)
- Buffering is beneficial and has low overhead
- Tradeoff between beaconing and buffering:

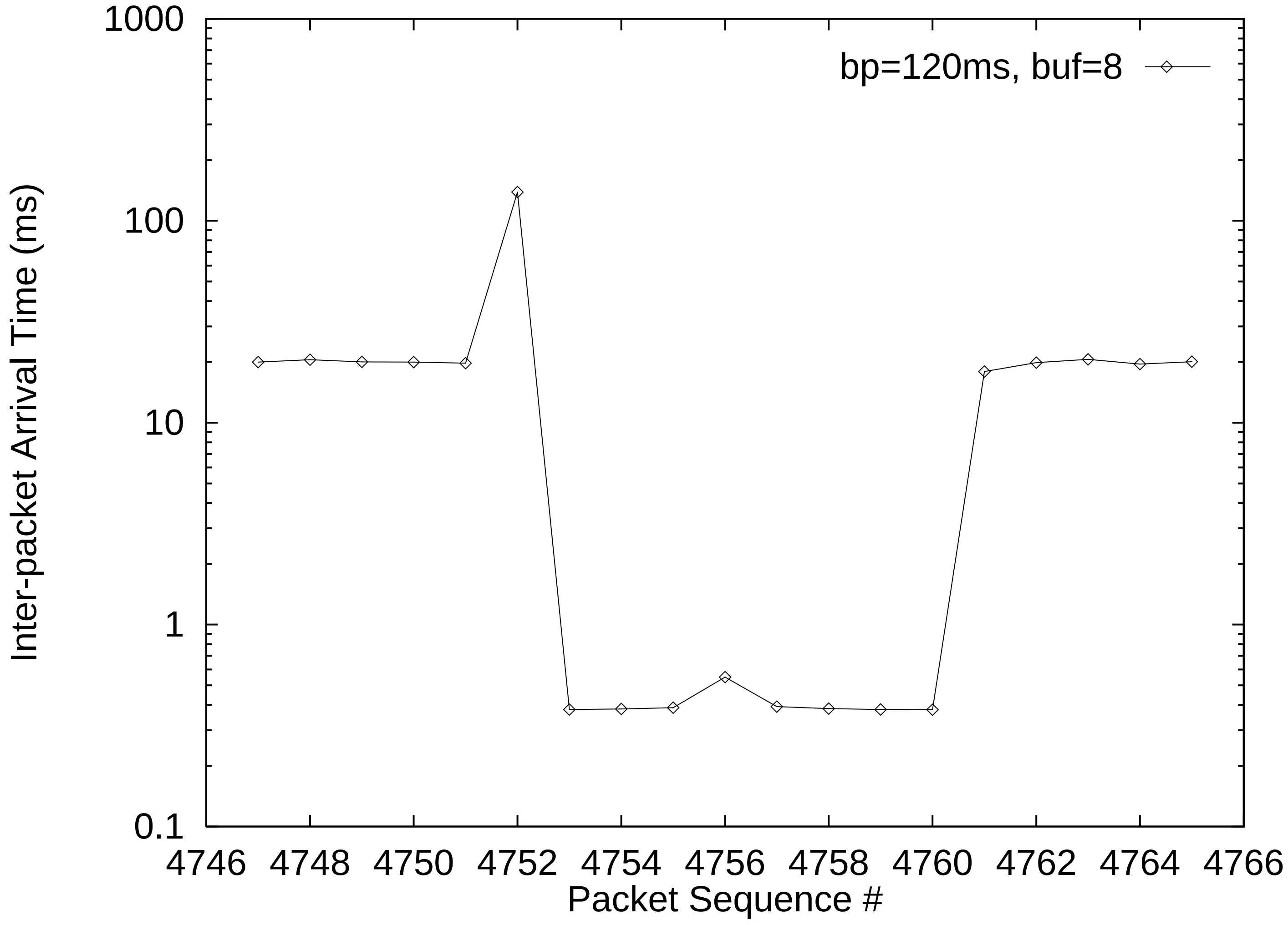
TCP: 120 ms beacon period and 5-10 packets of buffer gives 98-99% of throughput without handoff

UDP:

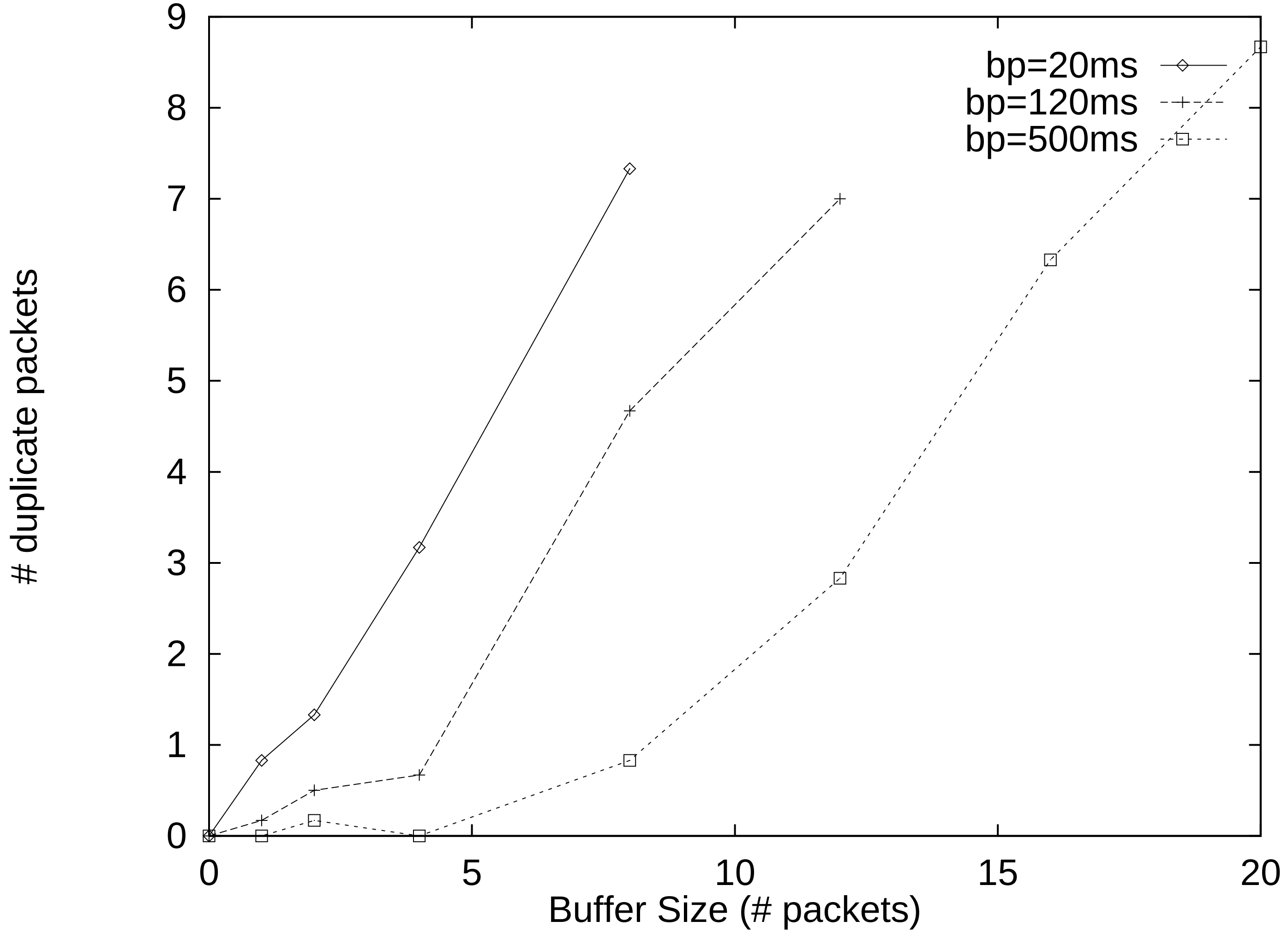
- Human ear sensitivity allows delay budget of 100-200 ms
- Application playout buffer hides jitter

So a beacon period around 100 ms with 5-10 packets of buffer (to avoid loss) seems a good choice

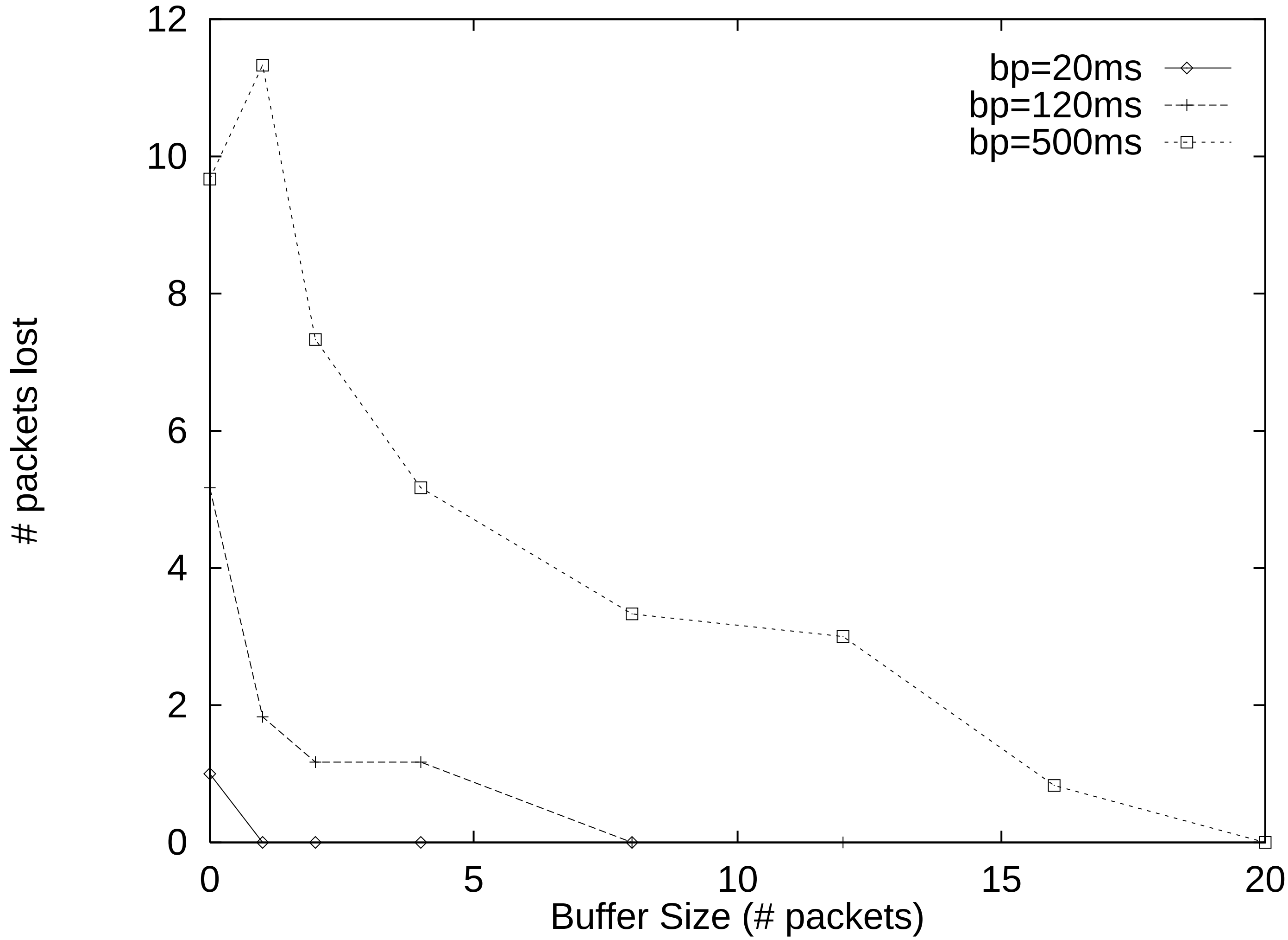
UDP Delay Jitter



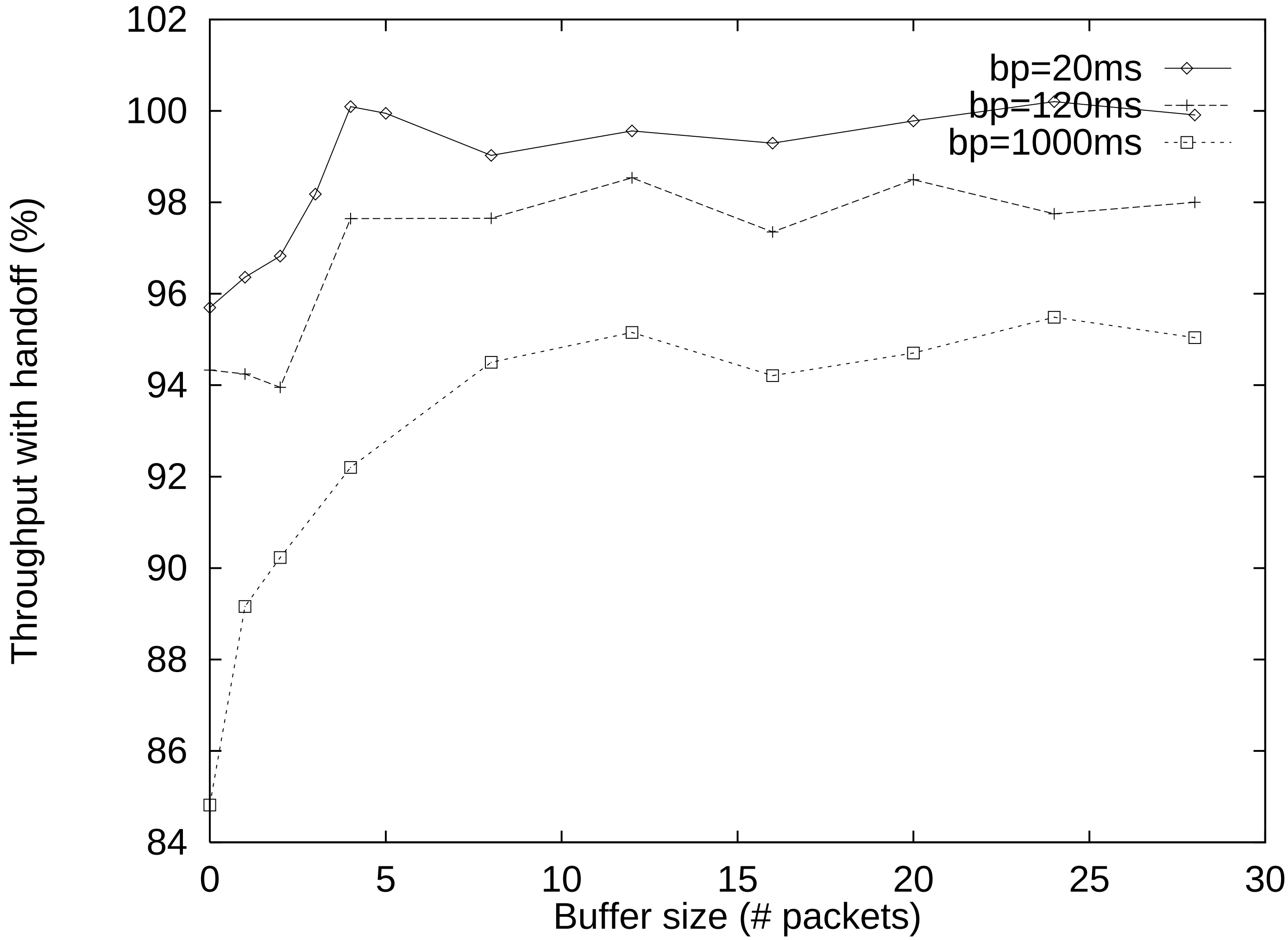
UDP Duplicate Packets



UDP Packet loss



TCP Throughput with handoff



TCP benchmark: `ttcp`

- Bulk-transfer applications (such as WWW)
- 2048 8 KB segments from local source to MH
- 2 handoffs in ~20 sec. duration

UDP benchmark: `udpbench`

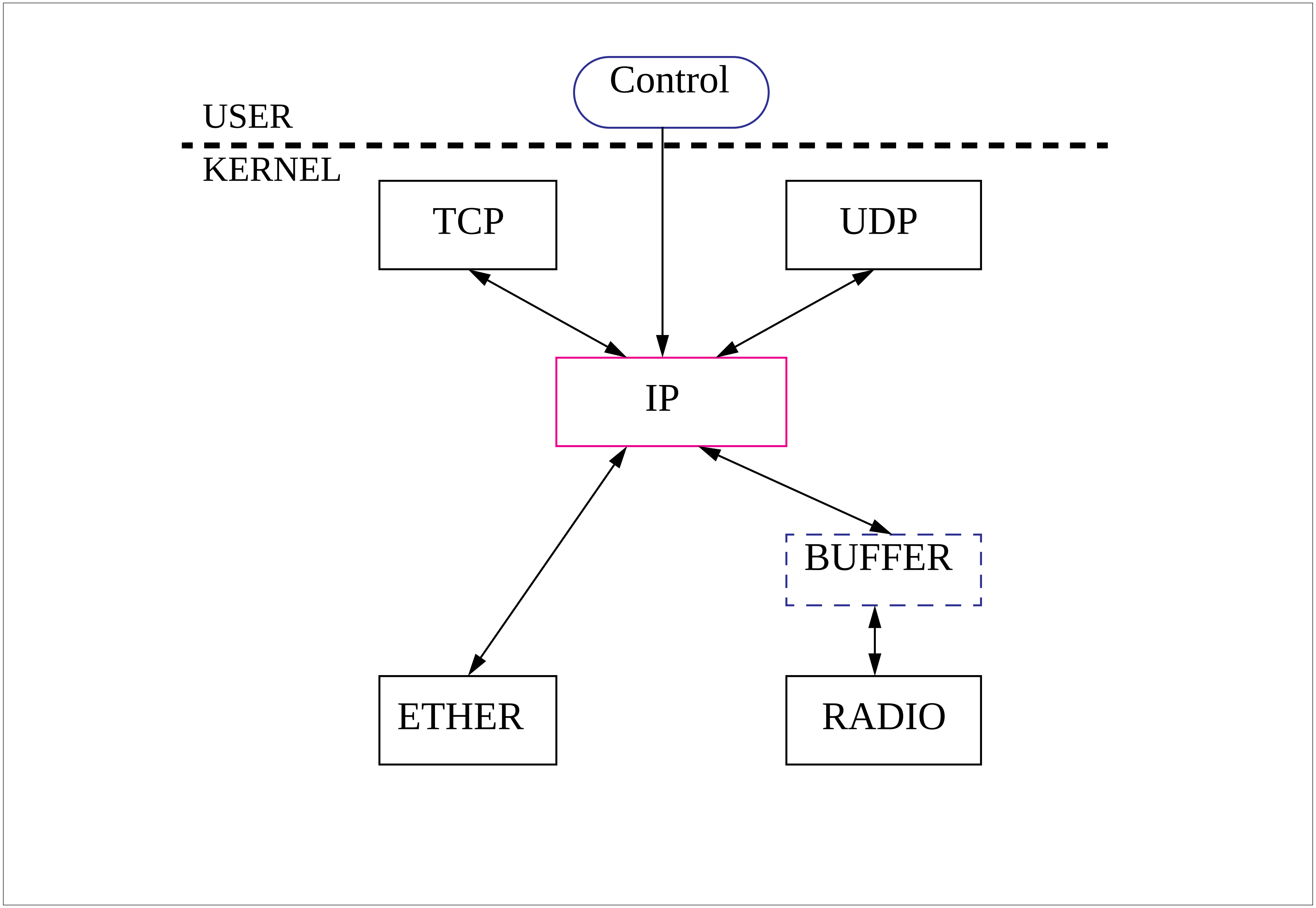
- Simulate a real-time application (`vat` audio stream)
- pcm: 20ms inter-packet spacing, 78 Kbps (200 byte average packet size)
- Playout delay: allows trading off buffer size for beaconing frequency
  - local conference: ~100 ms
  - remote conference: ~4-5 sec.
- Negligible reordering of packets
- Delay jitter due to retransmission

Experimental Results

- Used separate ethernet instead of wireless network
- Cisco router ignores ICMP redirects, so used source on local net
- Simulated handoff with no cell overlap (eg. IR networks)

Basic handoff mechanism:

- Rendezvous time: depends on beacon period (varied from 20 ms to 1 sec)
- Handoff time: 3-5 ms
- Buffering overhead: negligible (a few pointer manipulations)
- Beaconing overhead:
  - 42 byte packet => 336 bps (1 sec beaconing)to 16.8kbps (20 ms beaconing)
  - ttcp throughput: 1-2% decrease in the worst case


Control
USER
KERNEL
TCP
UDP
IP
BUFFER
ETHER
RADIO

Implementation

Solaris 2.4 in-kernel implementation

Protocol messages:

- 42 bytes in size (ICMP packets)
- Generated and processed by the IP driver
- REDIRECT: special ICMP Redirect to gateway
- Periodic beaconing helps ensure reliability

Buffer module:

- Streams module that can be pushed/poped using modified `ifconfig`
- Automatically registers itself with IP
- Buffers packets using `dupmsg`
- To retransmit, it sends packets back to IP for re-routing

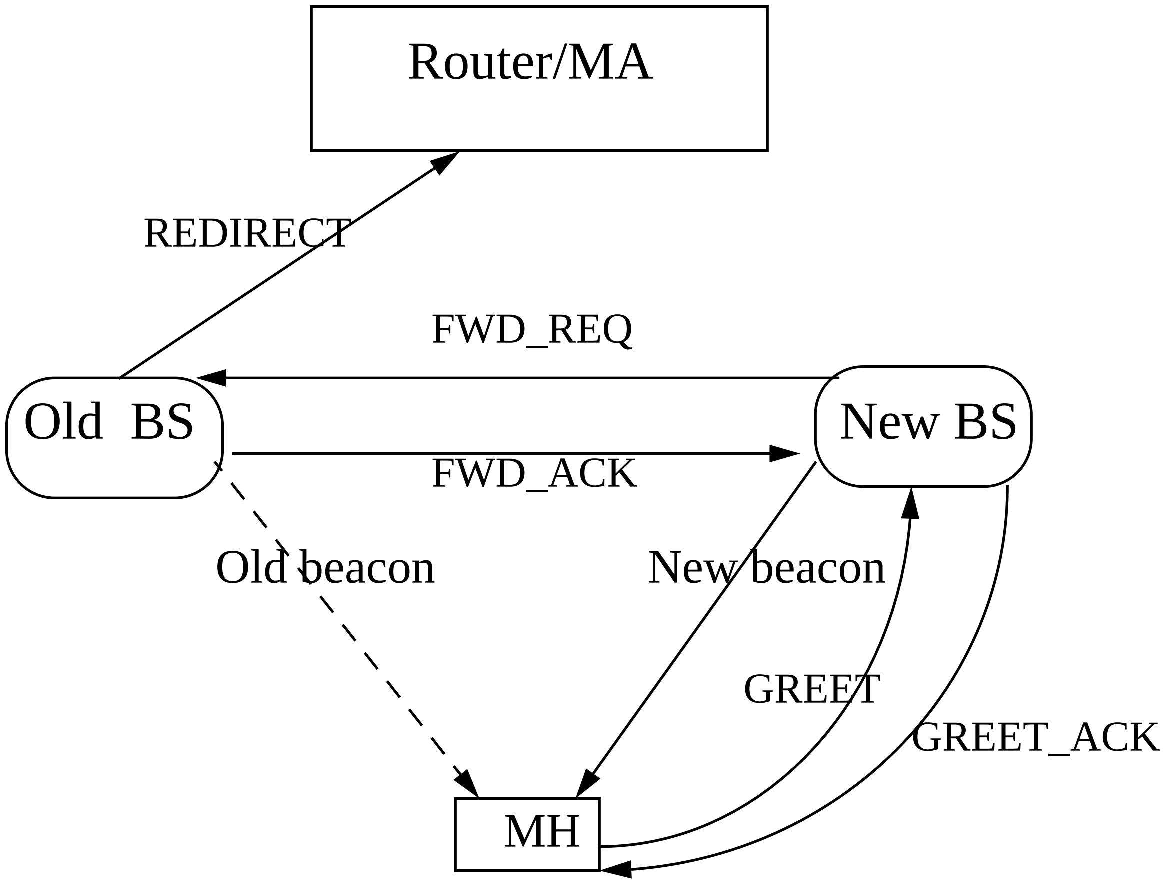
Advantages:

- IP vs. ATM: Per-mobile processing rather than per-connection
- Portable: independent of underlying network
- But easy to move to MAC layer: learning bridges instead of IP layer processing
- Can use location information from level 1 to improve level 2 handoff

Disadvantages:

- No QoS guarantees (but applications can adapt)

Light-weight handoff protocol



Old BS: on getting FWD_REQ

- Switches routing entry for MH
- Re-transmits buffered packets
- Sends FWD_ACK to old BS
- Sends REDIRECT to router (not in critical path)

Level 2:

- Each BS broadcasts MA advertisements onto wireless network
- Rest of handoff processing identical to Mobile-IP

Handoff Protocol

Level 1:

Periodic beacons from Basestations (BS)

MH: on getting new beacon

- Changes default gateway
- Sends GREET to new BS

New BS: on getting GREET

- Switches routing entry for MH
- Sends FWD_REQ to old BS
- Sends GREET_ACK to MH

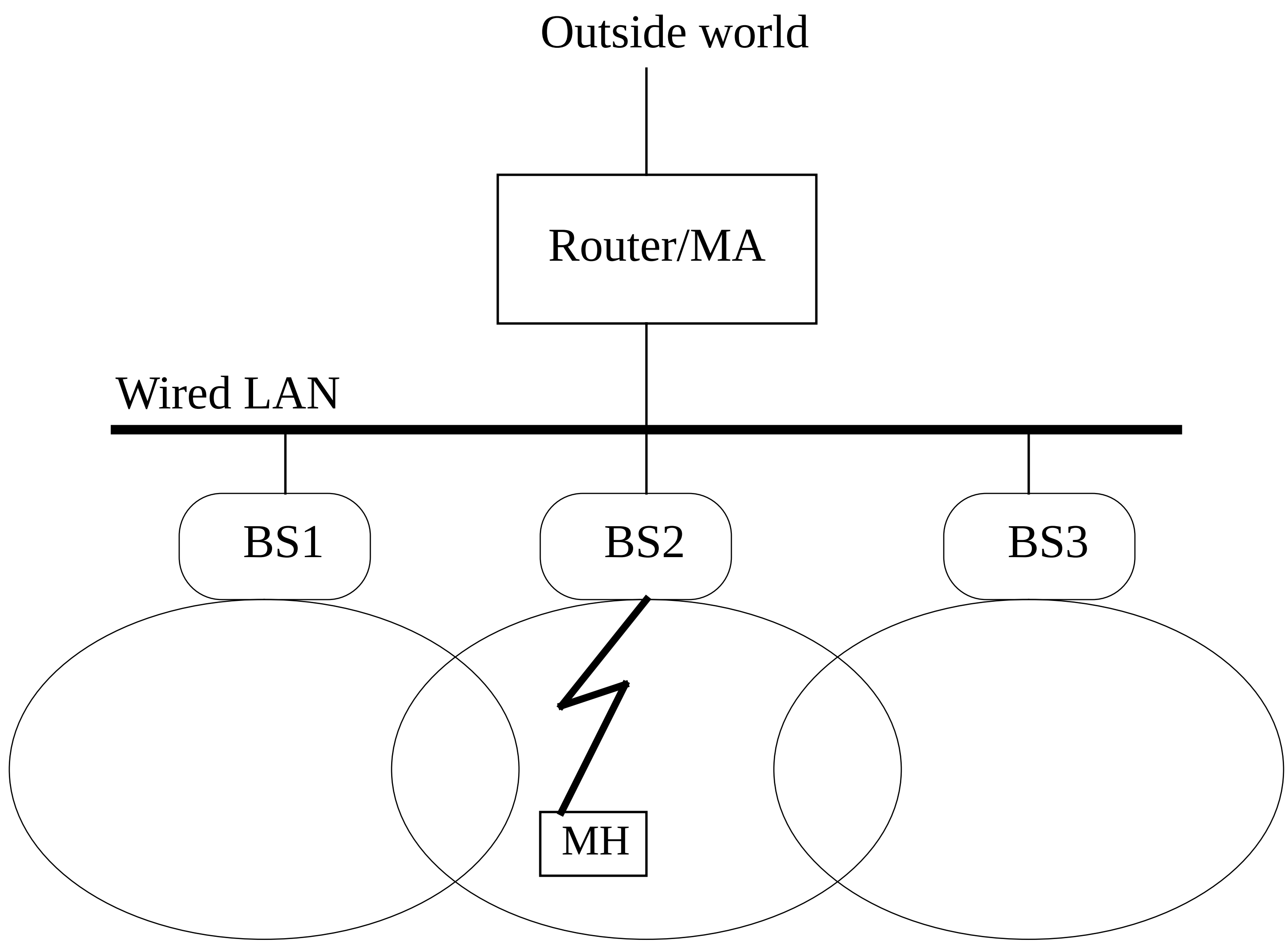
Network Architecture

Level 1:

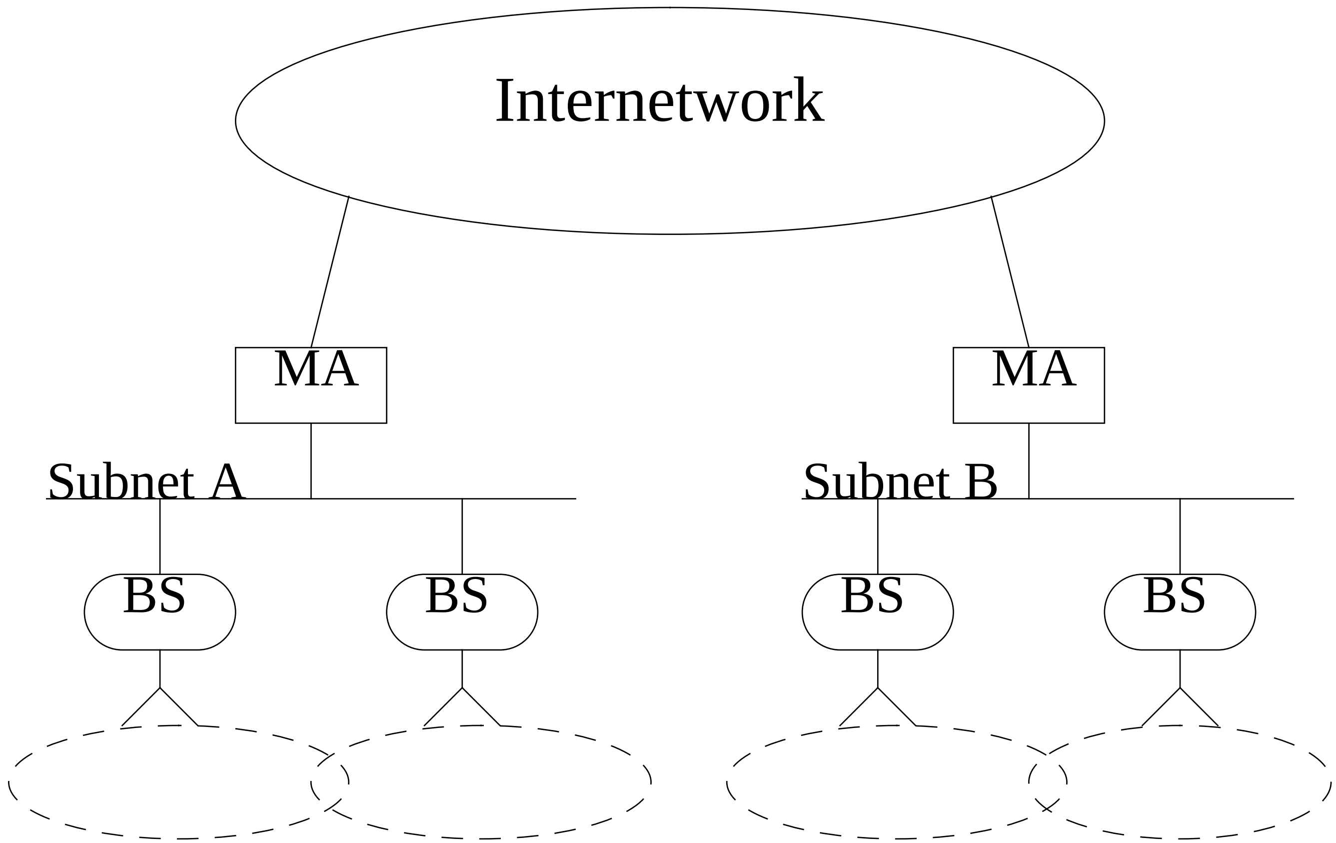
- Within the same administrative/security domain
- Basestations with fast wired connectivity
- Hides local mobility from the outside world
  - reduced update traffic
  - reduced update load on mobility agents (MA)
- Light-weight handoff

Level 2:

- Mobile-IP to handle movement across subnets


Outside world
Router/MA
Wired LAN
BS1
BS2
BS3
MH

■ ■


Internetwork
MA
MA
Subnet A
Subnet B
BS
BS
BS
BS

■

Motivation

- Locality in user mobility
- Survey: about 75% of professionals are “mobile”.
  50% of them mainly stay within the building
- Continuous-media applications require fast handoff (a few 10s of ms)
- Mobile-IP is a heavy-weight protocol
  - security
  - interaction with home agent
  - encapsulation
- Need for a light-weight handoff mechanism at the local level

Problem Definition

Wireless LAN (Example: WaveLAN):

- Multiple microcells cover a office environment
  - Better frequency reuse, lower power
  - Increased handoff frequency
- Applications of interest:
  - TCP-based (such as WWW browsing)
  - UDP-based (such as packet telephony)

Goals:

- Develop an architecture for supporting mobility efficiently in wireless networks
- Quantify performance

Outline

- Problem Definition
- Motivation for a 2-level Architecture
- Design and Implementation of the first level
- Experimental Results

  - `ttcp` (TCP benchmark)

  - `udpbench` (UDP benchmark)
- Conclusions and Future Work

An Architecture to Support Fast Handoffs in Wireless Networks

Venkata N. Padmanabhan

University of California at Berkeley

Mentor: Ramon Caceres

August, 1995