SIP-Based Proactive Handoff Management for Session Continuity in the Wireless Internet

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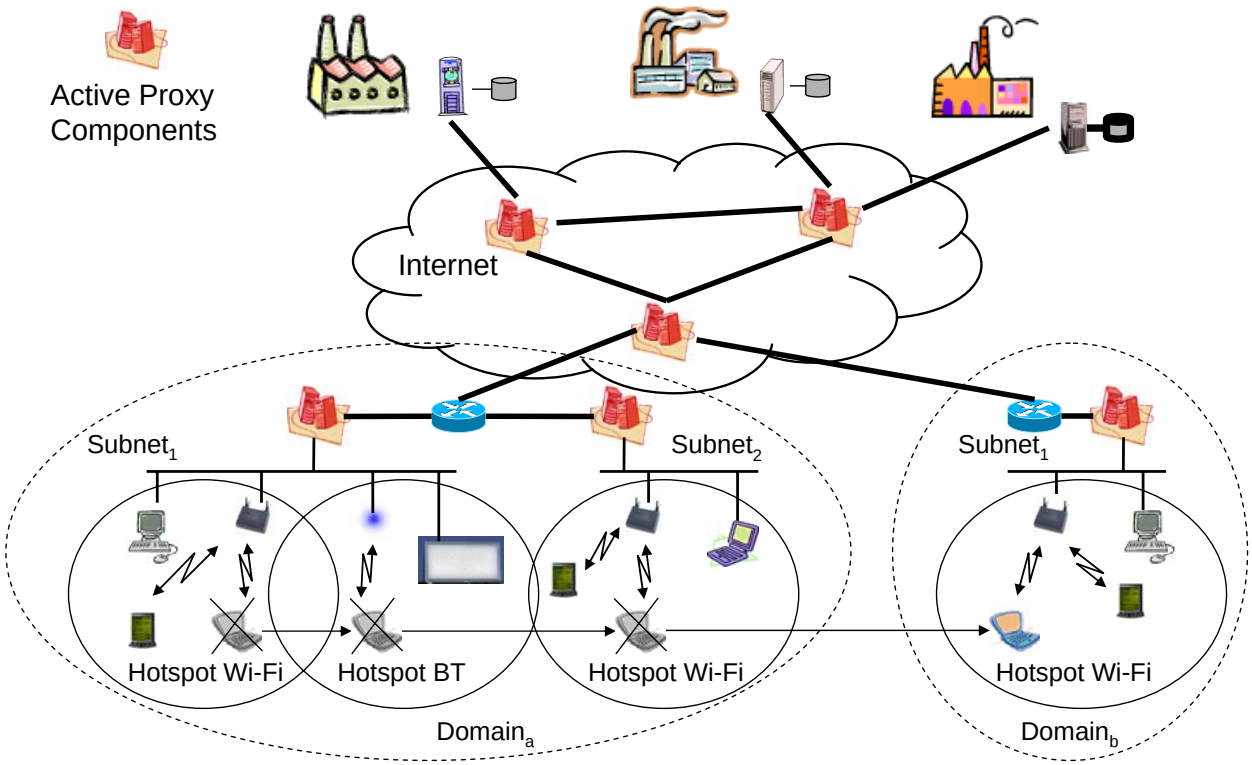
Agenda

- Application scenario
- Handoff management infrastructures
  - Multimedia service delivery in Wireless Internet
  - Context-aware handoff management
  - Proxy-based handoff middleware
- MUM active middleware
  - SIP framework
  - MUM SIP-based architecture
  - MUM package for SIP context-aware events
- Experimental evaluation
- Conclusions and ongoing work

Application scenario



Active Proxy-based Solutions

- Proxy-based solutions in fixed Internet
  - Web caching, re-directing, …
- Distributed **QoS** and **resource management**
  - **Active service paths** including client, servers, and one or more intermediate nodes, e.g., ReSerVation Protocol (RSVP)
- Suitable **design alternative** for wireless Internet environments
  - Proxies can **take over** mobile client **responsibilities** and **overcome** their **limitations**
  - Facilitate interaction between mobile clients and servers
    - Mobility, heterogeneity, …

Next Generation of Mobile Multimedia Services

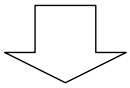
- Multimedia services
  - **Session** management
  - QoS management → data flow **continuity**
  - Application-level data flow control
    - Connection-less protocols, e.g., RTP/UDP

Session Continuity

- Wireless Internet (WI) design constraints
  - **Ubiquitous** and **continuous** access
    - Mobile users willing for **moving** in WI-enabled environments **during** service provisioning
  - High **heterogeneity**
    - Mobile devices, hardware/software distribution, …
  - Service provisioning exploits **various** wireless access **technologies**

Need for Context-Awareness

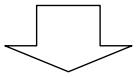
- **Various** access **technologies**
  - Different static and dynamic properties
- Unpredictable behavior of wireless medium
  - **Sudden changes** of network conditions: delay, bandwidth, Received Signal Strength Indicator (RSSI), …



- **Context awareness**
  - **Enables** advanced **session management** operations aimed to guarantee **session continuity**
  - **Requires** easy access to relevant **low-level** and **technology-dependent** information

Need for Context-Aware Handoff Management

- Handoff from one Access Point (AP) to another
  - **Horizontal**: within the **same infrastructure**
  - **Vertical**: between **different infrastructures**
- Problems
  - **Unpredictable delays** and **intermittent discontinuities** are **critical** for mobile multimedia streaming applications
  - **Dynamic monitoring** of the provisioning environments and **re-negotiation** of session parameters



Effective handoff management can be achieved only with a **tight relationship** between **context awareness** and **handoff execution**

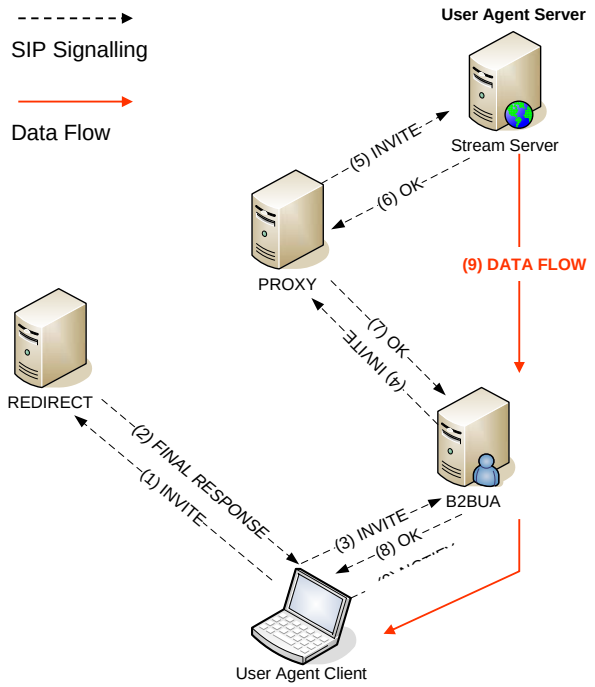
Proxy-based Middleware for Session Continuity

- **Application level middleware** for context-aware **handoff management** of **service session**
  - **Service session** information: data flows characteristics, user preferences, negotiated QoS levels, …
  - **Context** information: access networks (Bluetooth, Wi-Fi,…), client device profiles, …
- **Proxy-based** infrastructures
  - **Suitable** solution **for WI era**
  - **Middleware glue** → extends client/server capabilities
    - **Buffering during handoff**, content adaptation, …
  - Able to **proactively** initiate handoff management execution
    - Device handoff **prediction**
- Existing frameworks for session management: **Session Initiation Protocol (SIP)**
  - Wide **acceptance**, **mobility** support, high **flexibility**

MUM Active Middleware

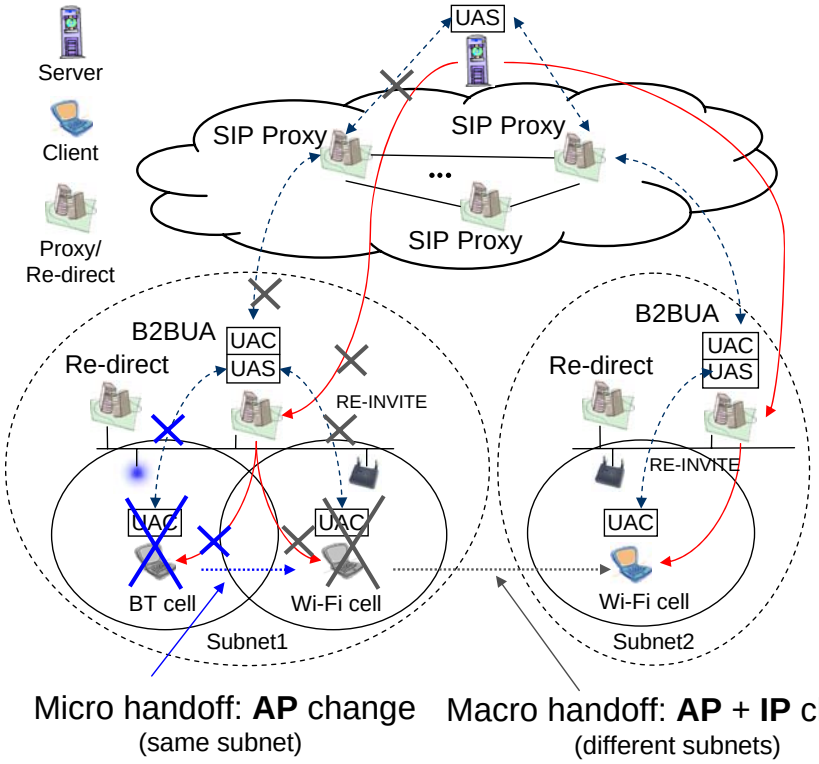
- **M**obile agent-based **U**biquitous multimedia **M**iddleware
- Service session continuity
  - Session **continuity maintenance**
  - Handoff management
- Active service paths
  - Server, one or more **active proxies** (one for each client) and client
- **MUM SIP-based architecture**
  - **Context-aware extensions** to SIP
    - To support proactive handoff management
  - **Interoperability** with SIP framework

SIP Framework



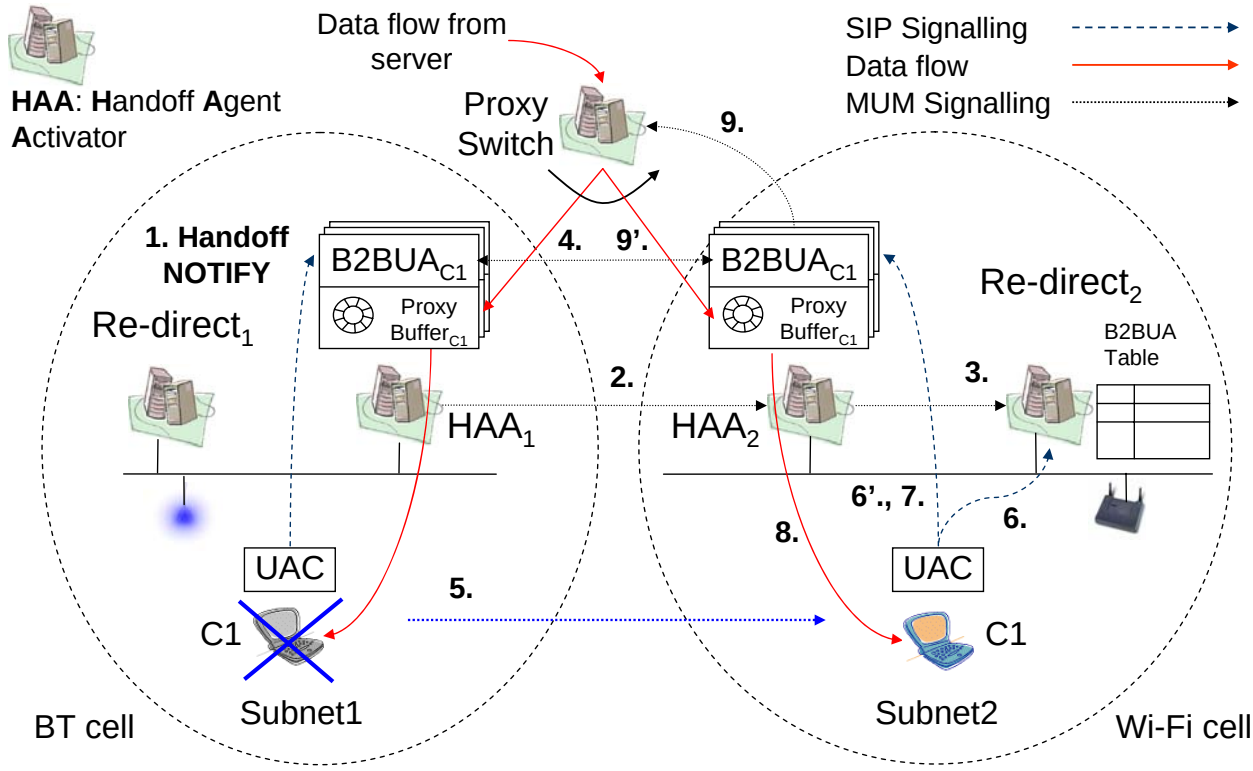
- Session Initiation Protocol (SIP)
  - IETF RFC 3261
  - Application level **session signalling** protocol:
    - INVITE, OK, ACK, …
  - **Proxy-based** architecture
- Main Entities
  - Session **signalling**: User Agent Server (**UAS**), User Agent Client (**UAC**), **Proxy**
  - Session **signalling** + **data flow provisioning**: Back to Back User Agent (**B2BUA**)
  - Support: **Redirect**
- Other extensions: "**Specific Event Notification**" (IETF RFC 3265)

SIP Framework: Mobility Support



- Mobility support
  - Very simple: RE-INVITE
  - Various types:
    - Session, personal, **terminal**, …
    - Micro and macro
- Proxy-based architecture → **local reconfigurations**
- Non context-aware
  - **No visibility** of **executing context** characteristics
  - **No** handoff **predictions**

MUM SIP-based Vertical Macro Handoff



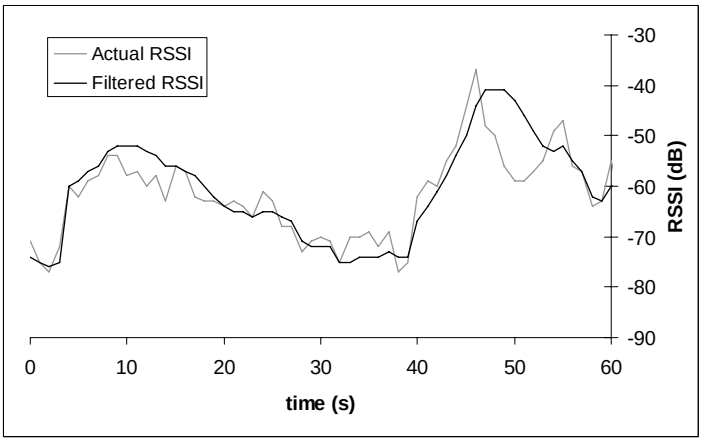
MUM Package for SIP Context-aware Events

```
NOTIFY sip:lucab2bua@192.168.3.20:3111;transport=udp SIP/2.0
Call-ID: nist-sip-invite-callId 1
CSeq: 5 NOTIFY
From: <sip:luca@192.168.3.1:6102>;tag=7064
To: <sip:lucab2bua@192.168.3.20:3111>;tag=3945
Via: SIP/2.0/UDP 192.168.3.1:6102;branch=z9hG4bK9ad3c15d5...
Max-Forwards: 70
Content-Type: application/contextAwarenessinfo+xml
Subscription-State: active
Event: contextAwareness
Content-Length: 473
```

```
<?xml version="1.0"?>
<!DOCTYPE contextAwareinfo SYSTEM "contextAwarenessinfo.dtd">
<clientinfo xmlns="urn:params:xml:ns:contextAwarenessinfo">
  <prediction aor="sip:luca@192.168.3.1">
    <type>vertical</type>
    <handoffProbability>high</handoffProbability>
    <oldAP>
      <type>BT</type>
      <coverageStatus>low</coverageStatus>
    </oldAP>
    <newAP>
      <type>WiFi</type>
      <coverageStatus>high</coverageStatus>
    </newAP>
    <newAPaddress>00:0D:29:3A:5F:72</newAPaddress>
  </prediction>
</contextAwareinfo>
```

- SIP Event Framework for Context Awareness
  - XML schema
  - → ***contextAwareness***
- Subscribe/Notify SIP messages header
  - Contact information
    - UAC, B2BUA
  - Package type: ***application/ contextAwareness***
- Handoff Notify message payload (step 1 previous slide)
  - Handoff type and probability
  - Old and new wireless cell technology and coverage status
  - AP MACs

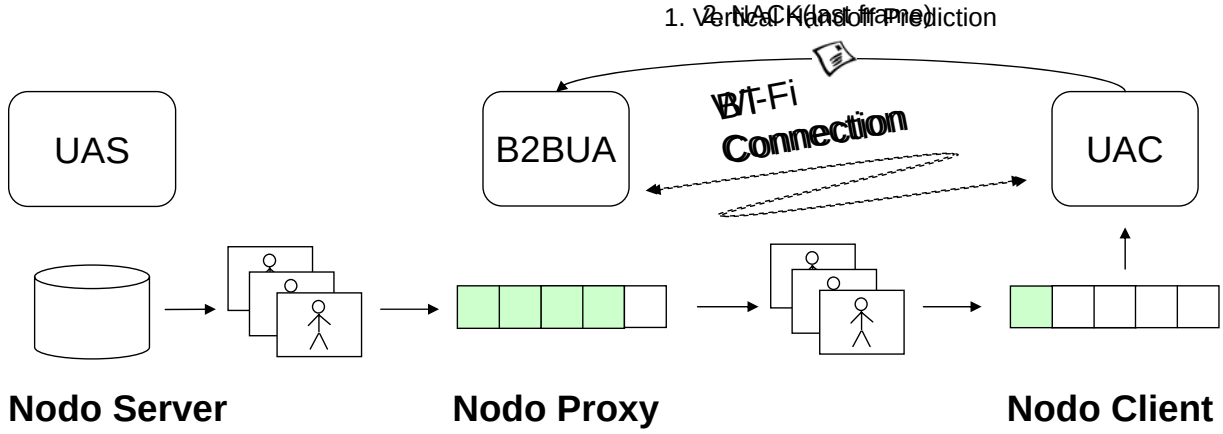
Handoff Prediction



$$pr(i) = \left(r_1(1) - \frac{u}{a} \right) e^{-ak} + \frac{u}{a}$$

- **RSSI** monitoring for all AP **in visibility**
- Grey Model for RSSI prediction/filtering
- RSSI obtained on **client node**
- Prediction algorothm execution on **client node**

Two Level Proactive B2BUA Buffering

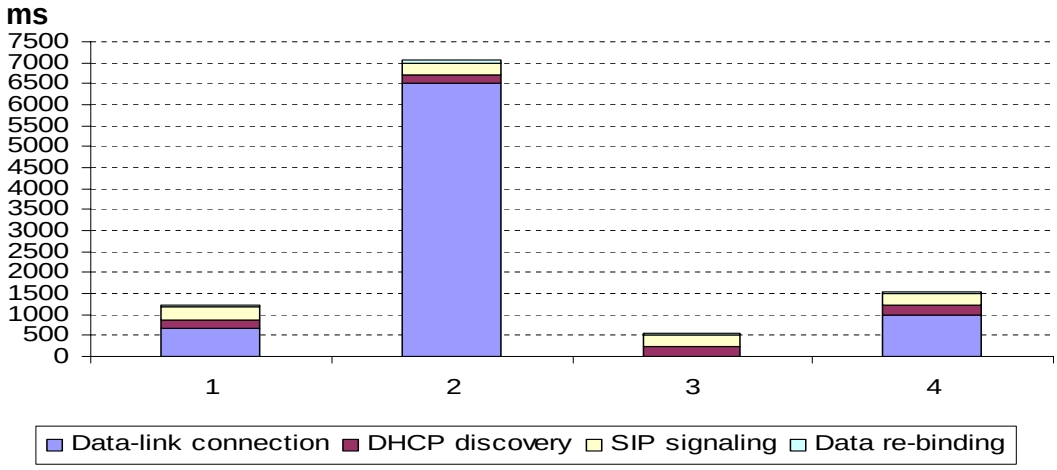


- Client buffer duration >= handoff duration
- Supported services: **VoD**, **Live Streaming**
- Normal conditions → **avoid** server-to-client locality retransmission due to packet losses

Implementation Hints and Experimental Testbed

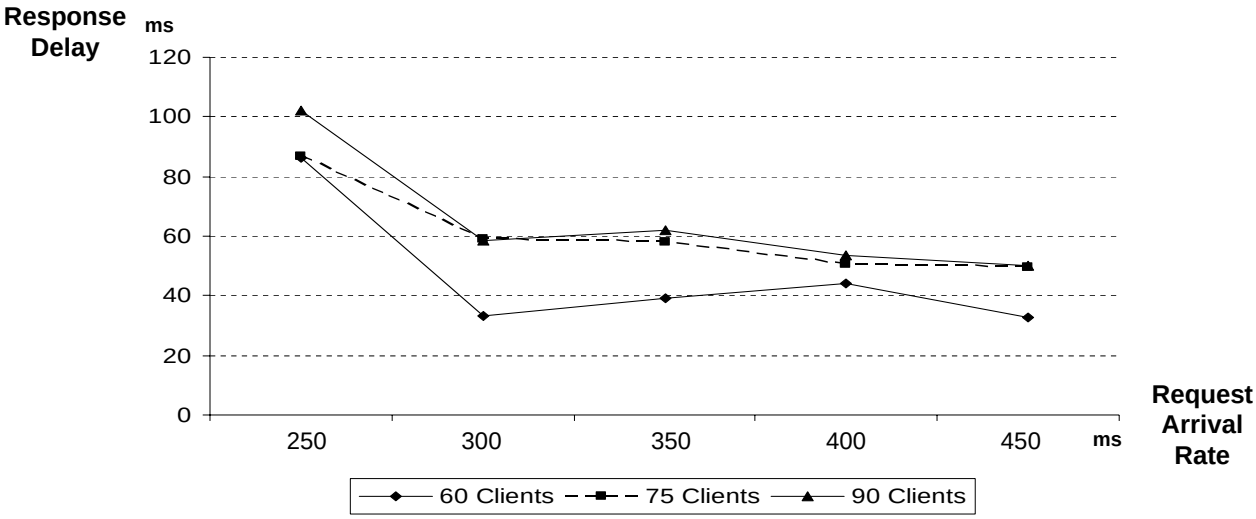
- Multimedia library: **J**ava **M**edia **F**ramework
  - Low level API
    - **Buffer management, easy-to-use and performant**
  - **Client** e **proxy**
  - **R**eal**T**ime **P**rotocol
  - H263 encoding
- Other system libraries and tools
  - NIST JainSIP
  - JDHCP 1.0.1
  - iwconfig, hcitool
- Experimental testbed
  - Client: Asus laptops connected by an IEEE 802.11b Cisco card and a Mopogo BT doungle, class 1, version 1.1
  - Proxy and Server: Dell PC, 3GHz, 512MB RAM, Linux Gentoo
  - Wireless infrastructures
    - Wi-Fi: Cisco Aironet 1100 AP
    - BT: Mopogo BT doungle, class 1, version 1.1

Vertical Handoff Performance



- **Without** proactive **discovery** of target access network
  - Case 1: BT → Wi-Fi (~1200ms), case 2: Wi-Fi → BT (~7s)
- **With** proactive **discovery** of the target network
  - Case 3: BT → Wi-Fi (~500ms), case 4: Wi-Fi → BT (~1,5s)

Vertical Handoff Scalability



- Delay between NOTIFY (sent by UAC) and OK (sent by B2BUA) at new AP
  - Request arrival-rate: Poisson distribution with inter-arrival time varying in the interval [250ms, 450ms]

Conclusions and Ongoing Work

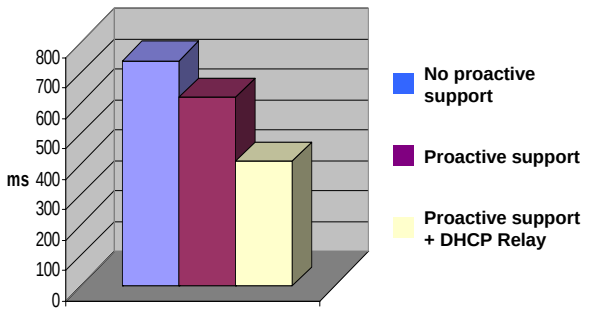
- Conclusions
  - SIP-based application-layer solutions are **suitable** in mobile **WI scenarios**
  - MUM handoff prediction and context-aware notifications **reduce handoff delays** and **guarantee session continuity**
- Ongoing work
  - **Soft-handoff** management techniques (BT and Wi-Fi)
  - Other optimizations: **DHCP-Relaying** techniques to further reduce IP address discovery time

Further Experimental Results

SIP Signalling Details

SIP Messages	Time (ms)
INVITE / ACK (to Redirect)	210
INVITE / ACK (to B2BUA)	154
DHCP Relay	256
RE-INVITE	443

RE-INVITE Optimizations



- CPU usage **overhead** on client node
  - Passive mode (pull interactions): **5%**
  - Active mode (push interactions): **21%**

Related Publications and Project Home Page

- Articles:
  - P.Bellavista, A.Corradi, L.Foschini, “MUM: a Middleware for the Provisioning of Continuous Services to Mobile Users”, *IEEE ISCC*, 2004
  - P.Bellavista, A.Corradi, L.Foschini, “MUMOC: an Active Infrastructure for Open Video Caching”, *IEEE DFMA*, 2005
  - P.Bellavista, A.Corradi, L.Foschini, “Java-based Proactive Buffering for Multimedia Streaming Continuity in the Wireless Internet”, *IEEE WoWMoM*, 2005

- Prototype code: **http://lia.deis.unibo.it/Research/MUM**

- Contacts: Luca Foschini, lfoschini@deis.unibo.it