IMS-based Middleware Solutions for Advanced Management of Mobile Multimedia Services

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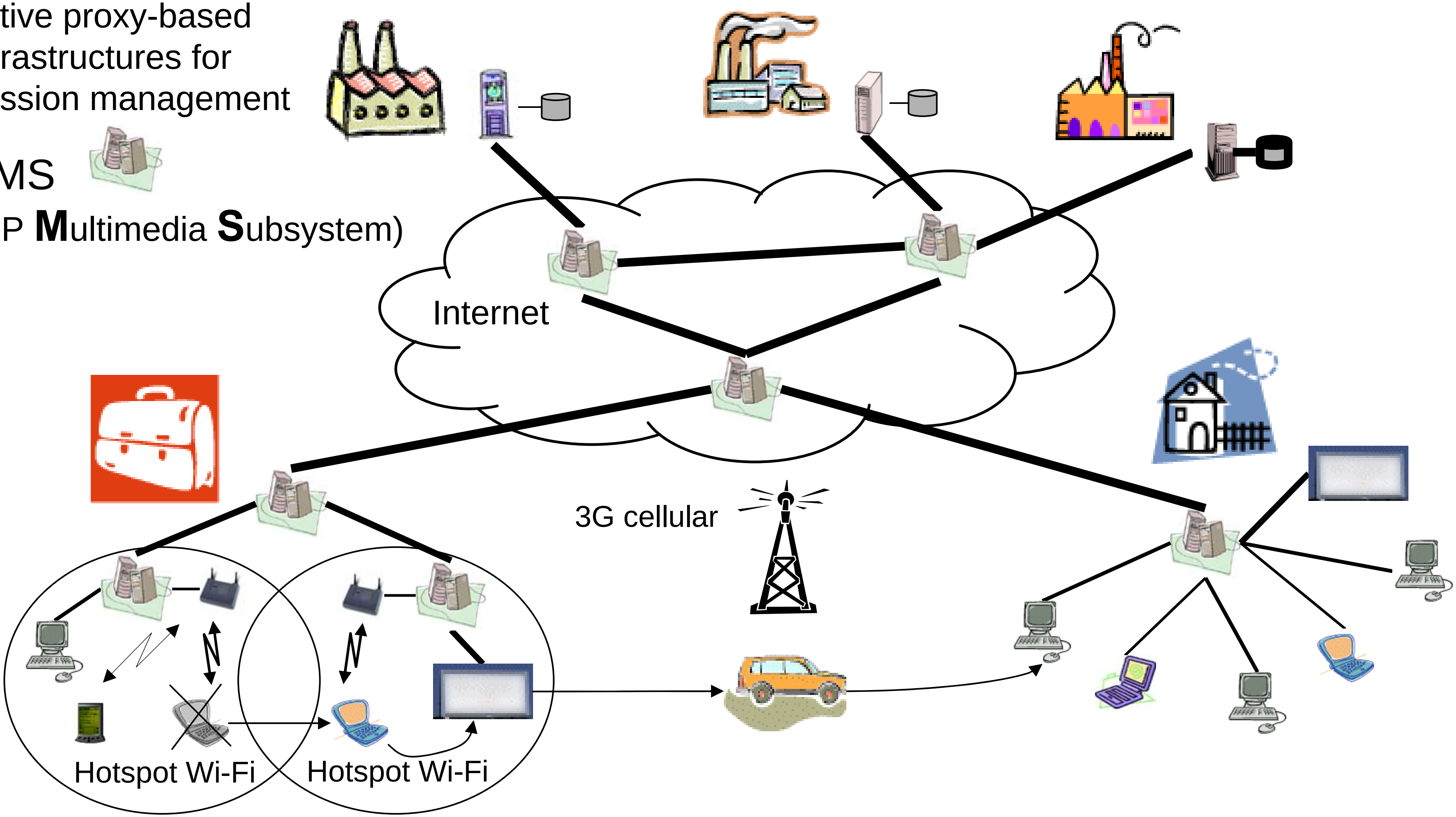
Agenda

- ***Multimedia service delivery*** for the ***wireless Internet***
- ***Middleware*** for ***IMS-based mobile multimedia services***
  - Context-aware management operations: handoff, content adaptation, power management, …
  - Scalability issues: distributed Presence Service deployments, IMS application server interposition,…
- ***Technical details*** and ***experimental evaluation*** (for each of above areas)
- Conclusions and other ongoing research efforts

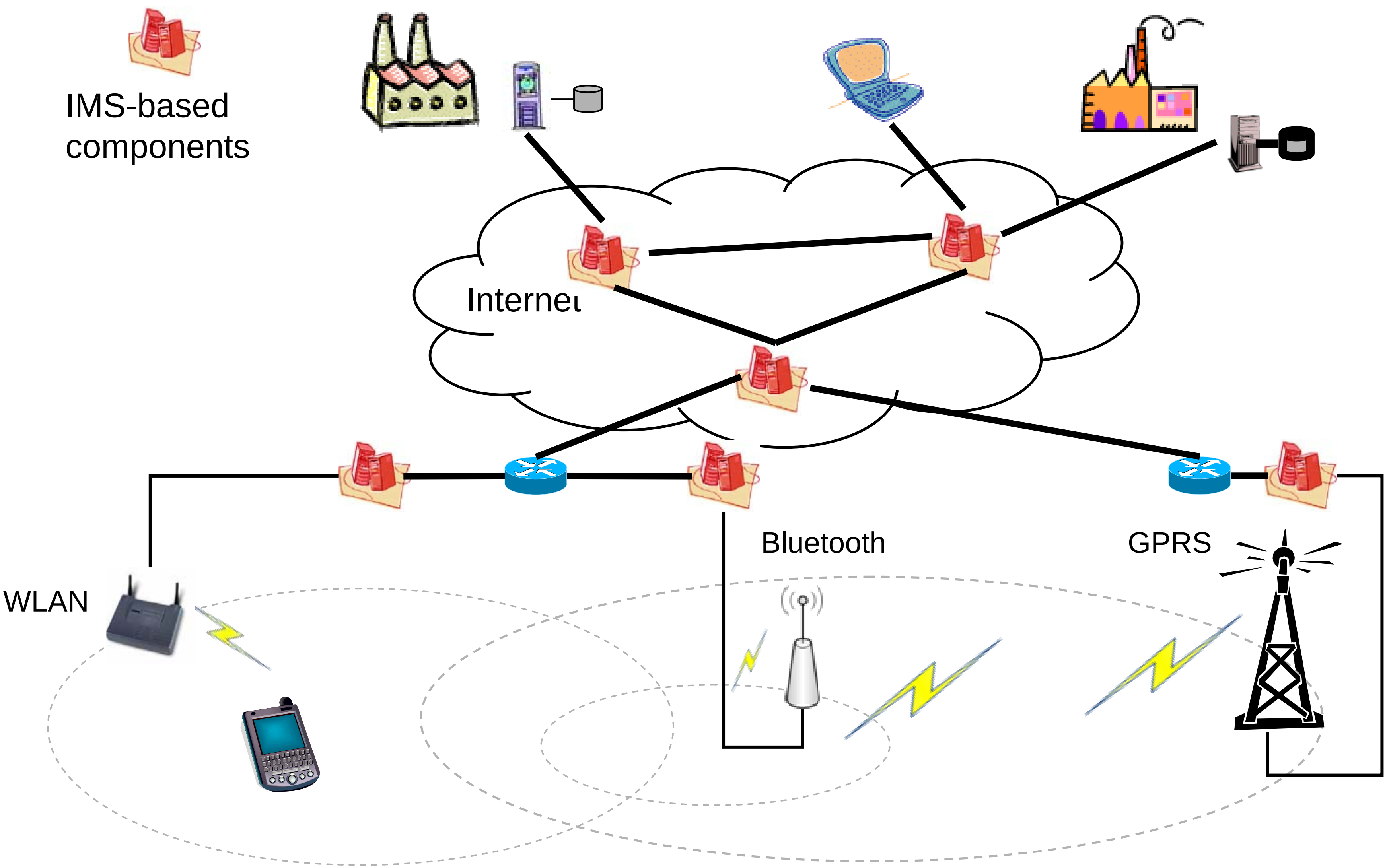
4G Converged Mobile Multimedia Scenario

New protocols and active proxy-based infrastructures for session management

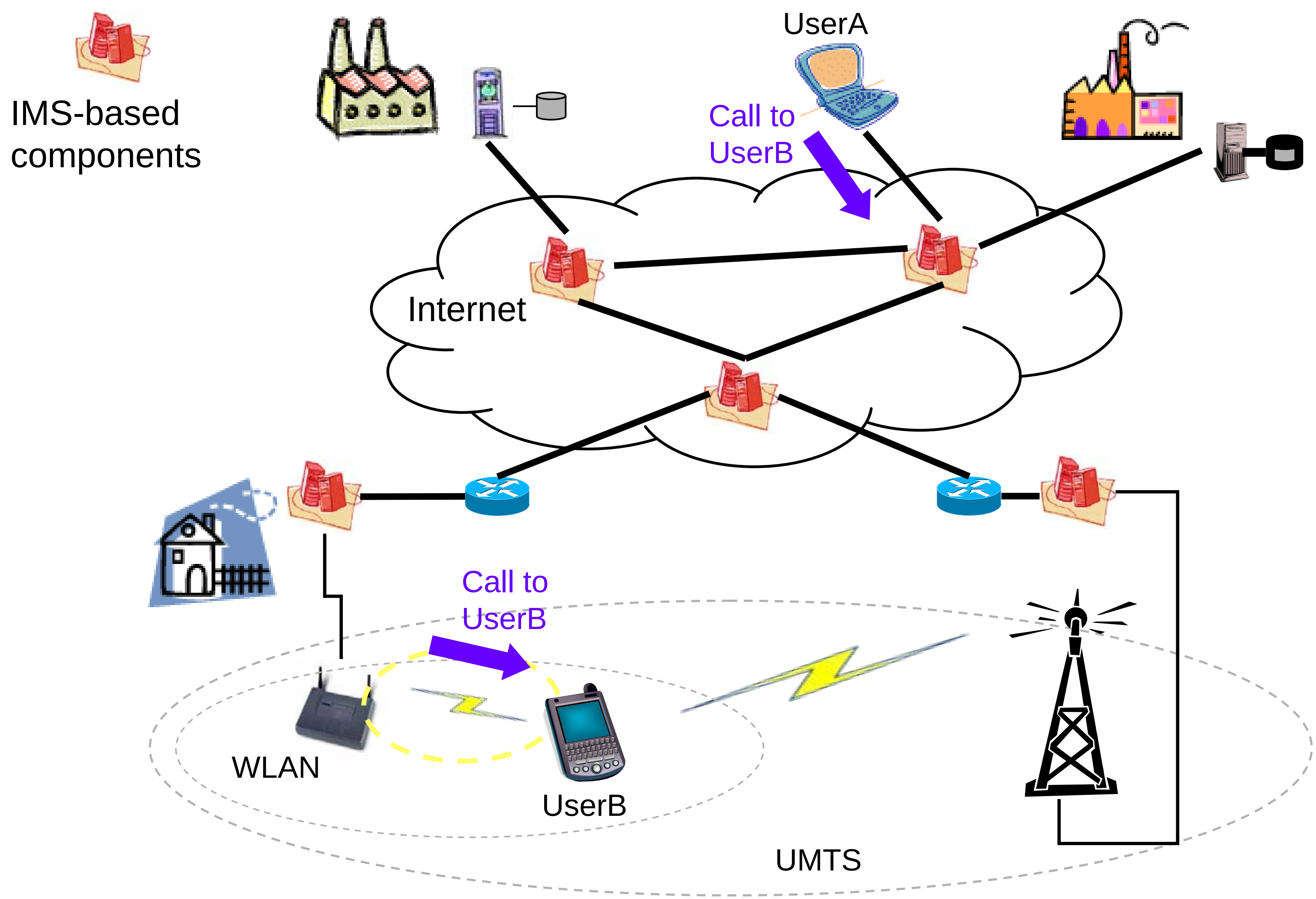
IMS
(IP Multimedia Subsystem)



Scenarios in the (wireless ☺) Internet: multimedia services handoff management



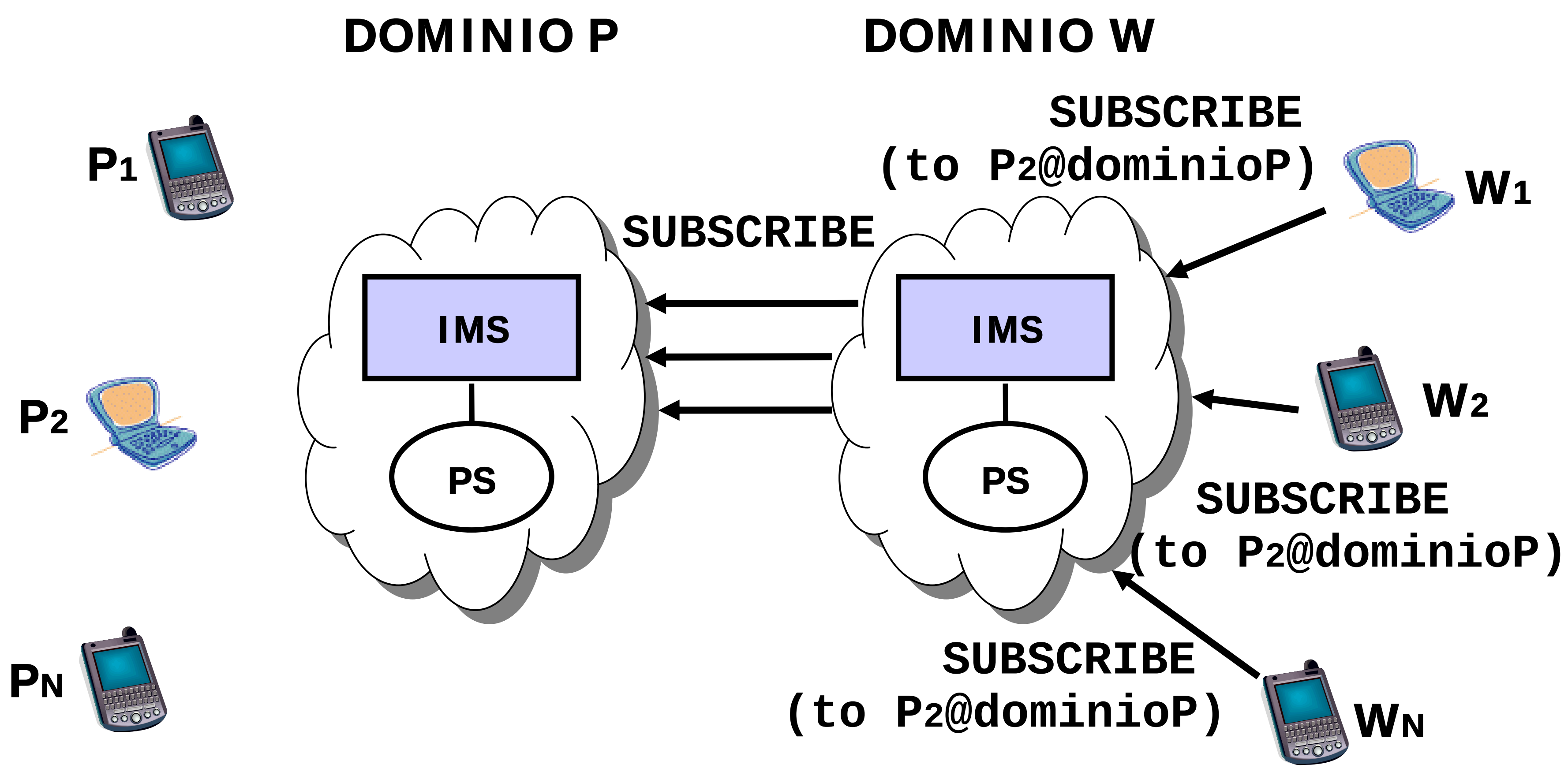
Scenarios in the (wireless ☺) Internet: multimedia services power management



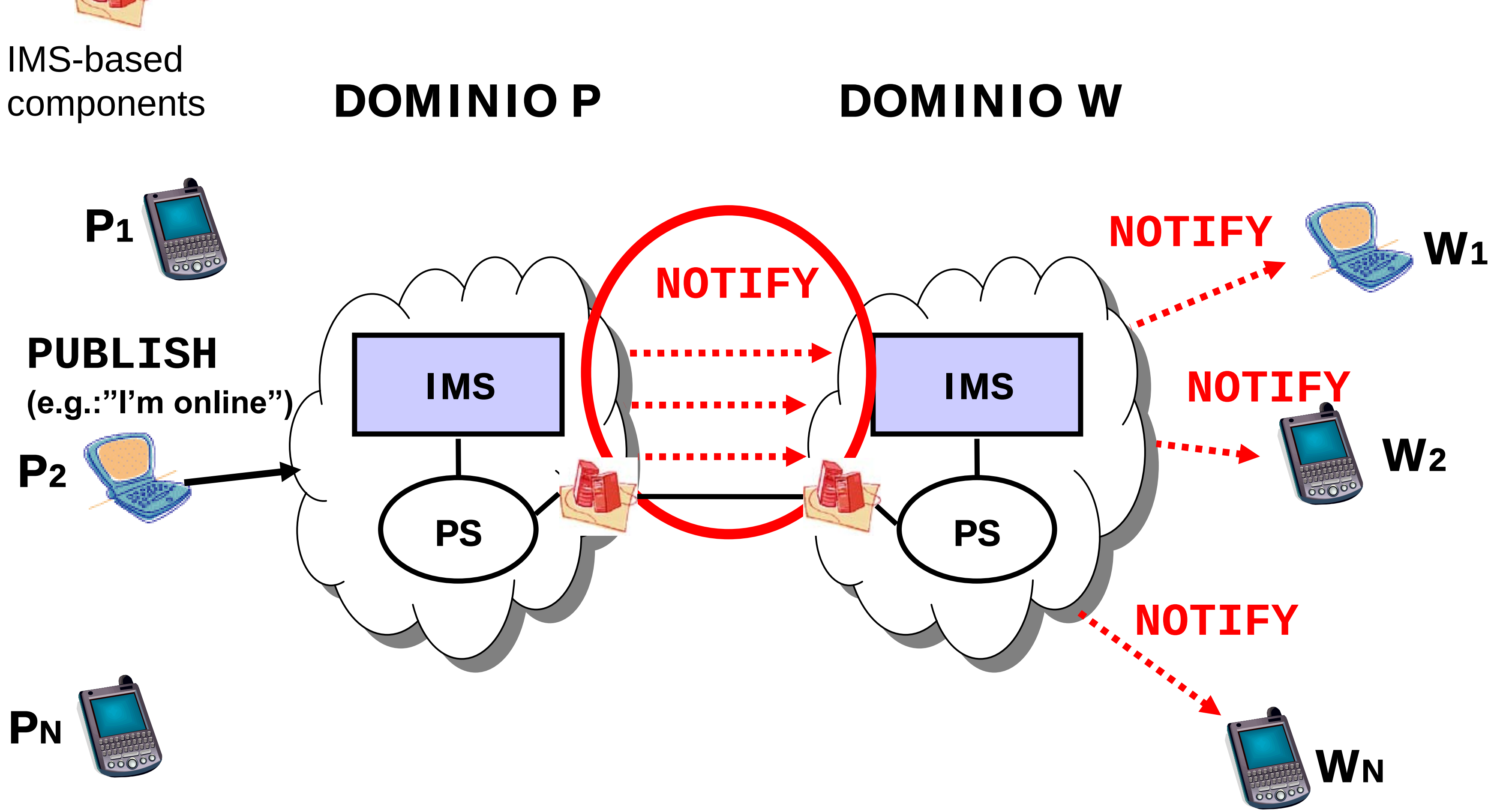
P: presentity **PS**: Presence Server

W: watcher

Inter-domain PS scenario



Inter-domain PS scenario



Problem: high number of inter-domain PS messages

Mobile multimedia services in the wireless Internet

- Mobile multimedia services requirements
  - **Ubiquitous** service provisioning
  - **Continuous** data flow delivery → ***service continuity*** (applications must specify Service Level Agreements, SLAs)
  - **Adaptive** service distribution (different clients, supported formats, user preferences, …)
- ***Wireless Internet*** (WI) challenges
  - Unpredictable user **mobility**: location, wireless technology, and Access Point (AP) change → ***handoff***
  - High variety of **wireless access technologies**
    - Bluetooth (BT), IEEE 802.11a/b/g (Wi-Fi), UMTS, …
    - Different **static** and **dynamic** properties
  - Scalability issues
    - Context-aware service management and personalization require to share and disseminate **a huge amount of** (client-side generated) **information**
    - Application-layer solutions (IMS) are more flexible ☺, but **more costly** ☹

Lower-layer mobile multimedia management approaches

- **Several** ad hoc solutions at **low** OSI stack **layers**
  - **Data-link** layer
    - Protocol enhancements, e.g., to **reduce energy consumption**
    - Several ongoing efforts to **increase bandwidth** and **enable mobility → emerging standards: WiMax, Long Term Evolutions (LTE), …**
  - **Network** layer
    - Mobility management
      - Data-link triggers/events to **reduce handoff latency**
      - Standardization efforts IEEE 802.21 **Media Independent Handover – MIH**
    - Handoff management
      - (Mobile IP and its optimizations)
      - Buffering and multicast techniques to **reduce data losses**
  - **Transport** layer
    - Content adaptation: end-to-end bandwidth monitoring/probing to **possibly adapt content delivery** (but tight application-transport layer coupling)

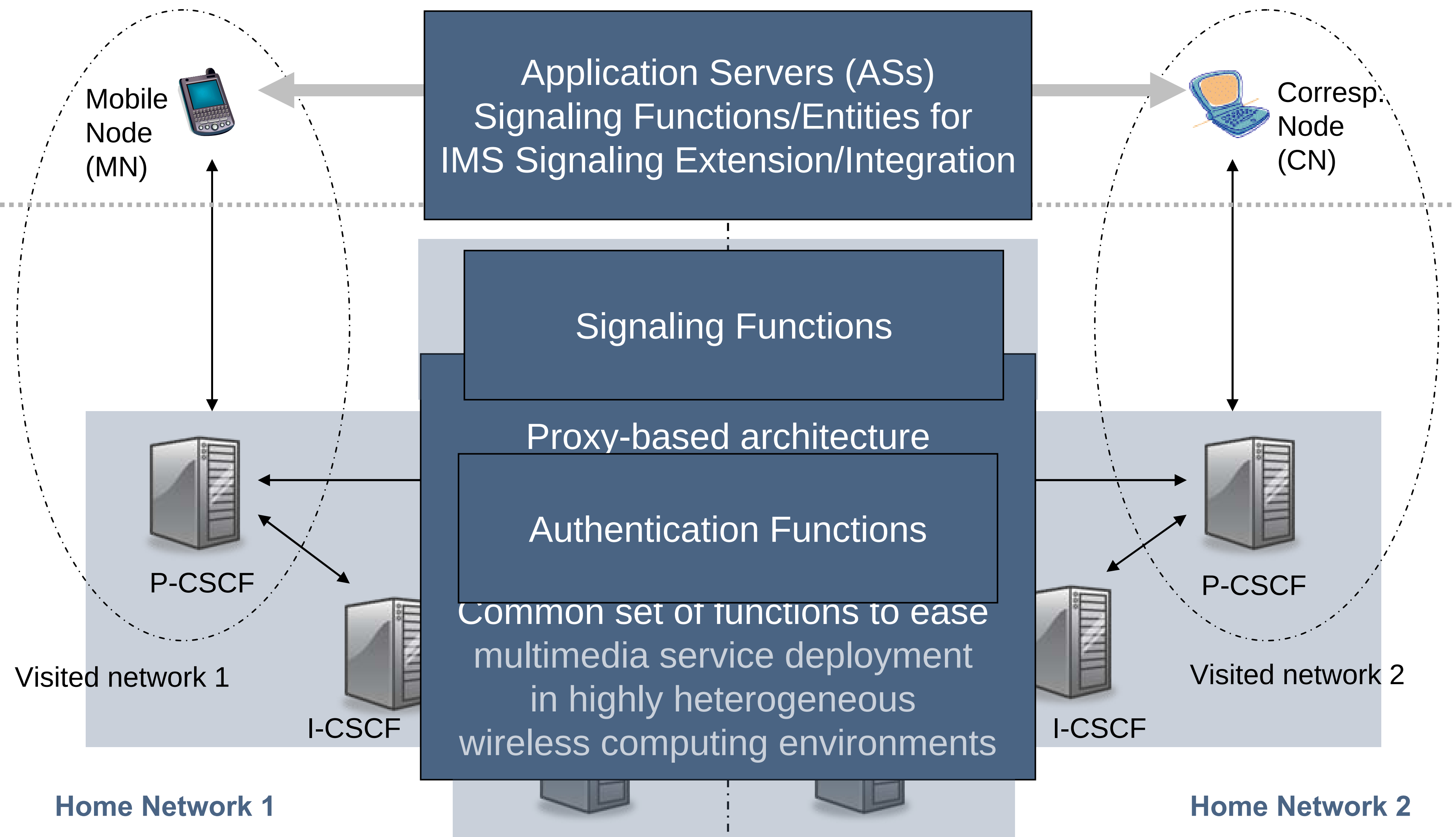
→ ***Efficient***, but ***not*** very ***flexible*** and ***context-aware***

Application-layer mobile multimedia management approaches

- **Few** proposals at the **application layer**
  - ***Ad-hoc solutions*** (non-standard and difficult to deploy in real environments)
    - Buffering and multicast to **reduce packet loss**
    - Power management to **lower energy consumption** at client devices
    - Content tailoring to **adapt multimedia flow provisioning**
  - ***Unable to exploit potential application-level*** visibility: often mimic network layer approaches
  - ***IMS-based*** (also SIP-based) ***solutions*** are starting to be recognized as an ***important evolution direction***
    - ***Call and session control*** infrastructures for next generation 4G networks
    - Active session control paths → ***proxy session control entities***
    - Support services → ***IMS Presence Service (IMS PS)***

BUT… IMS scalability issues not tackled yet

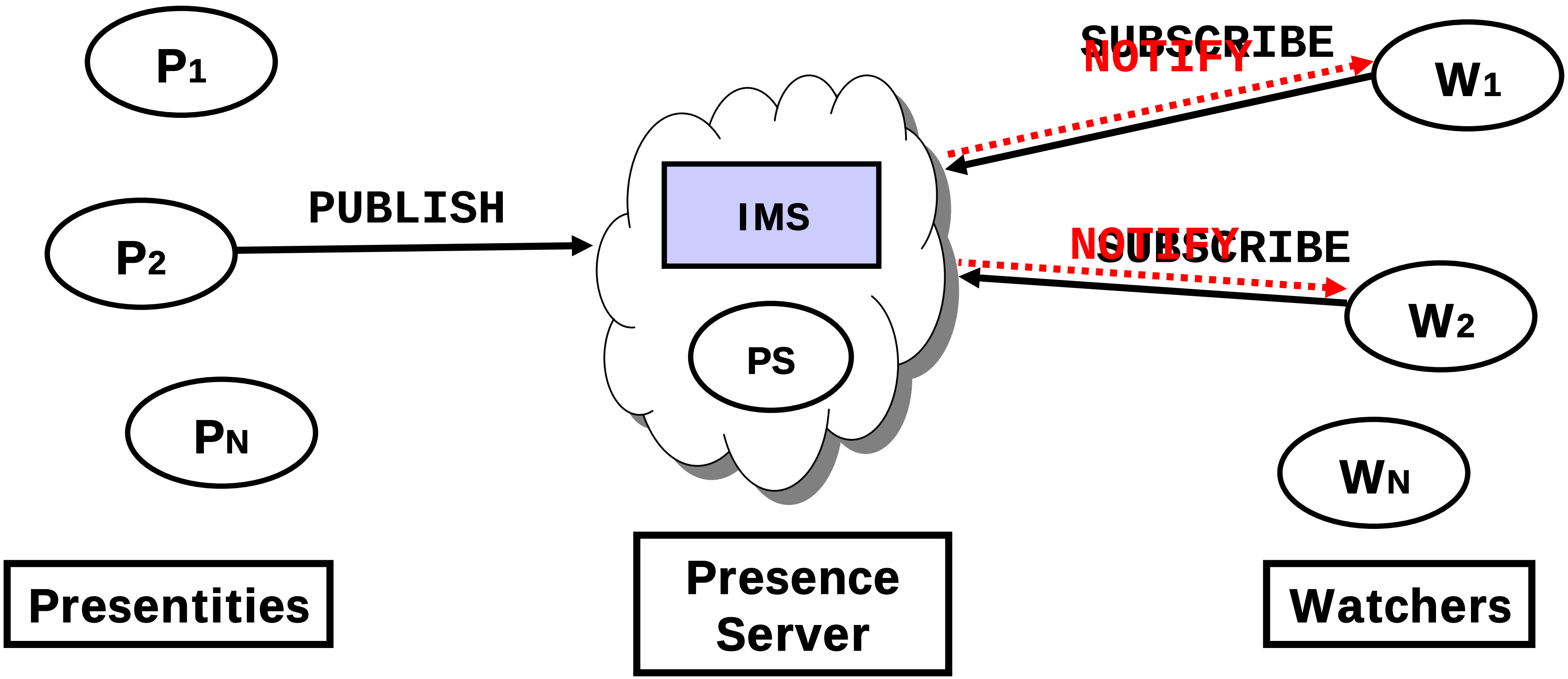
IMS – IP Multimedia Subsystem



IMS PS – IMS Presence Server

Presence service (PS) permits users and hw/sw components, called ***presentities (P_i),*** to convey their ability and willingness to communicate with subscribed ***watchers (W_j)***.

IMS standardizes PS as a specific AS → ***IMS PS***

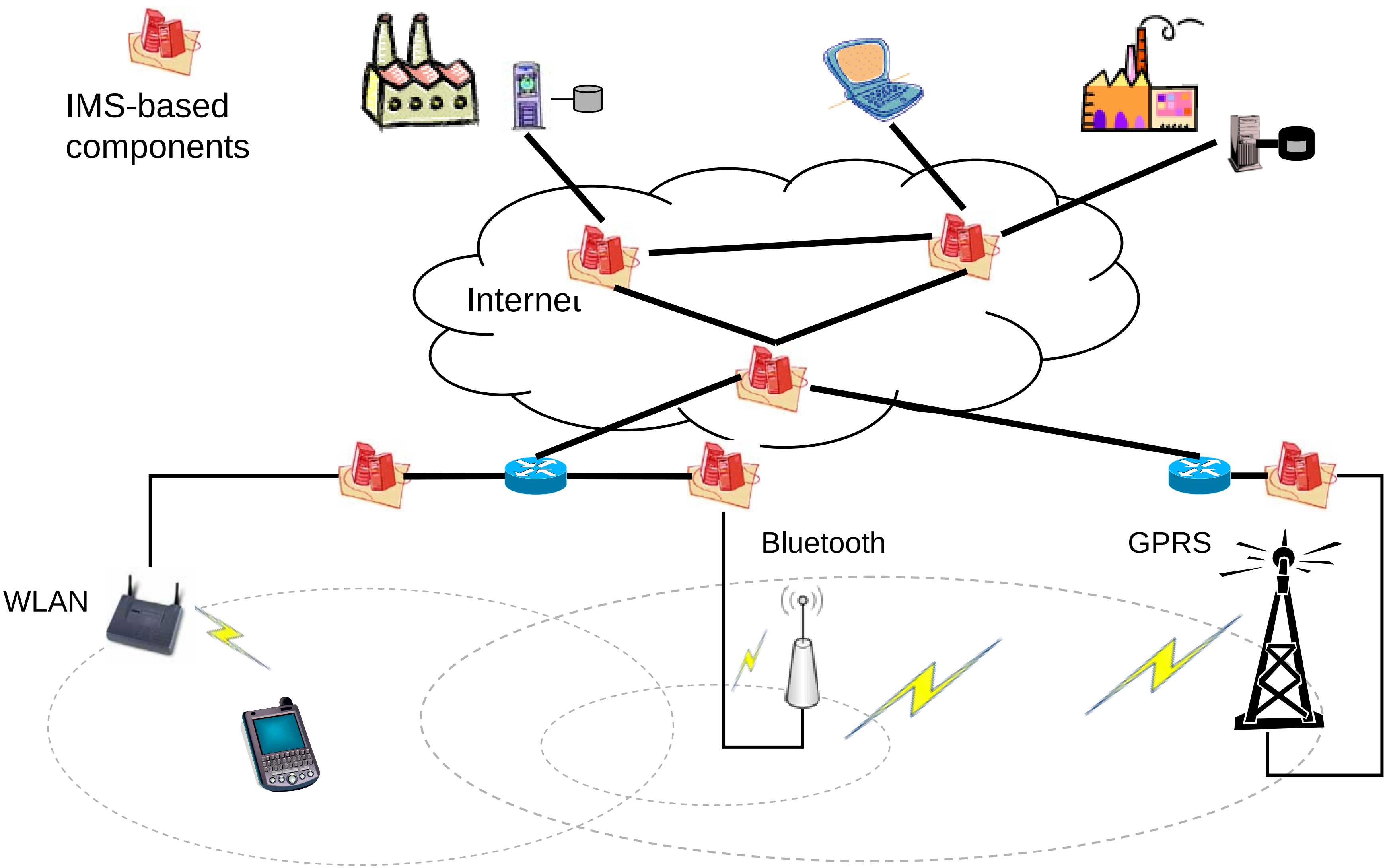


IHMAS active middleware

IMS-compliant **H**andoff **M**anagement **A**pplication **S**erver

- Multimedia session continuity
  - ***Session signaling enhancements*** for power management
- Active session signaling and media data paths
  - Dynamic session signaling and re-direction (for ***handoff management***, ***power management***, and ***service optimization)***
- IMS-compliant solutions
  - Session management entities realized as a ***novel IMS AS***
  - AS performs specific management operations
- Application-level approach
  - **Seamless integration** with existing services (e.g. ***IMS PS*** to deliver ***context updates*** about mobile node)

IHMAS handoff management

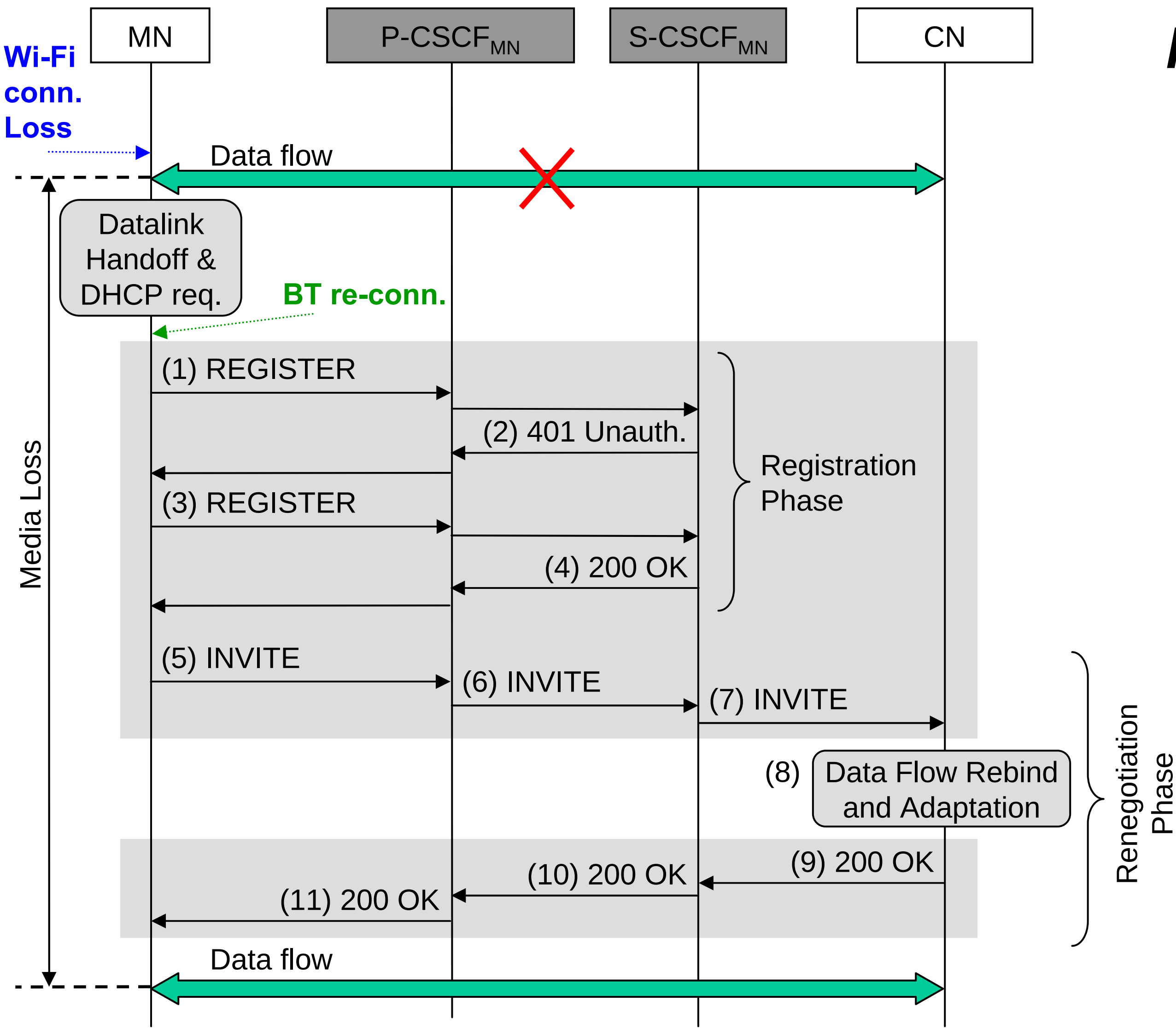


- Handoff types
  - **Horizontal** within the **same infrastructure** (BT→BT)
  - **Vertical** between **different infrastructures** (BT→Wi-Fi)

- Long and highly variable **handoff latencies** → ***relevant packet losses***
- **Collected** vertical hard handoff latency (data-link layer)

Vertical Handoff: Target Card Model	***Handoff Latency: Mean ± St. Dev. (s)***	
BT → Wi-Fi	***High Converage***	***Low Coverage***
Intel Wi-Fi	0,384 ± 0,072	0,971 ± 0,163
Orinoco Wi-Fi	0,487 ± 0,064	0,584 ± 0,067
Wi-Fi → BT	***High Converage***	***Low Coverage***
Mopogo BT	1,553 ± 0,250	3,633 ± 0,438
Asus BT	1,765 ± 0,239	3,734 ± 0,651

IMS Vertical Handoff Protocol: Open Issues



Main Problems

- ***Reactive*** and ***sequential*** handoff execution approach
- Prone to ***long delays*** and ***media losses***

May degrade any service, but ***especially multimedia services*** (with guaranteed arrival rate requirements for the whole session)

IHMAS Handoff Management

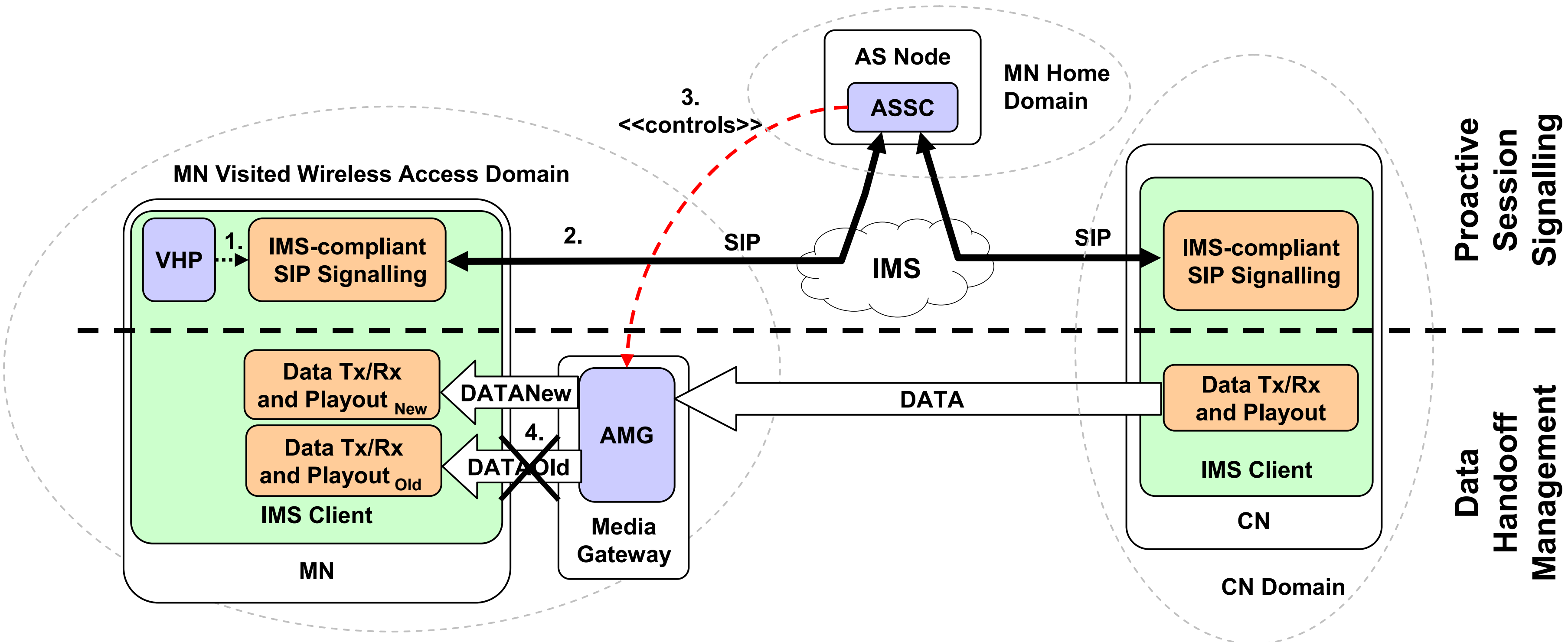
- ***Context-aware*** handoff management ***middleware***
  - **extracts** and **monitors** low level parameters (Received Signal Strength Indicator, inter-arrival packet delay, …)

    → ***vertical handoff prediction***
  - **executes** application-level specific
    - **session signaling actions**
    - **multimedia flow tailoring operations**

    → ***dynamic content adaptation***
  - **integrates** seamlessly with existing infrastructures

    → ***full compliancy with IMS standard***

IHMAS Vertical Handoff Facility: Distributed Architecture



- Vertical Handoff Predictor – ***VHP*** (one for client): RSSI filtering and handoff prediction
- AS for Service Continuity – ***ASSC*** (one for IMS domain): realizes vertical handoff protocol enhancements
- Adaptation Media Gateway – ***AMG*** (one for access locality): content adaptation

Implementation Insights: Vertical Handoff Predictor

Several ***mobility prediction solutions*** have been investigated (*ad-hoc positioning/velocity detection, history&profile, …*)

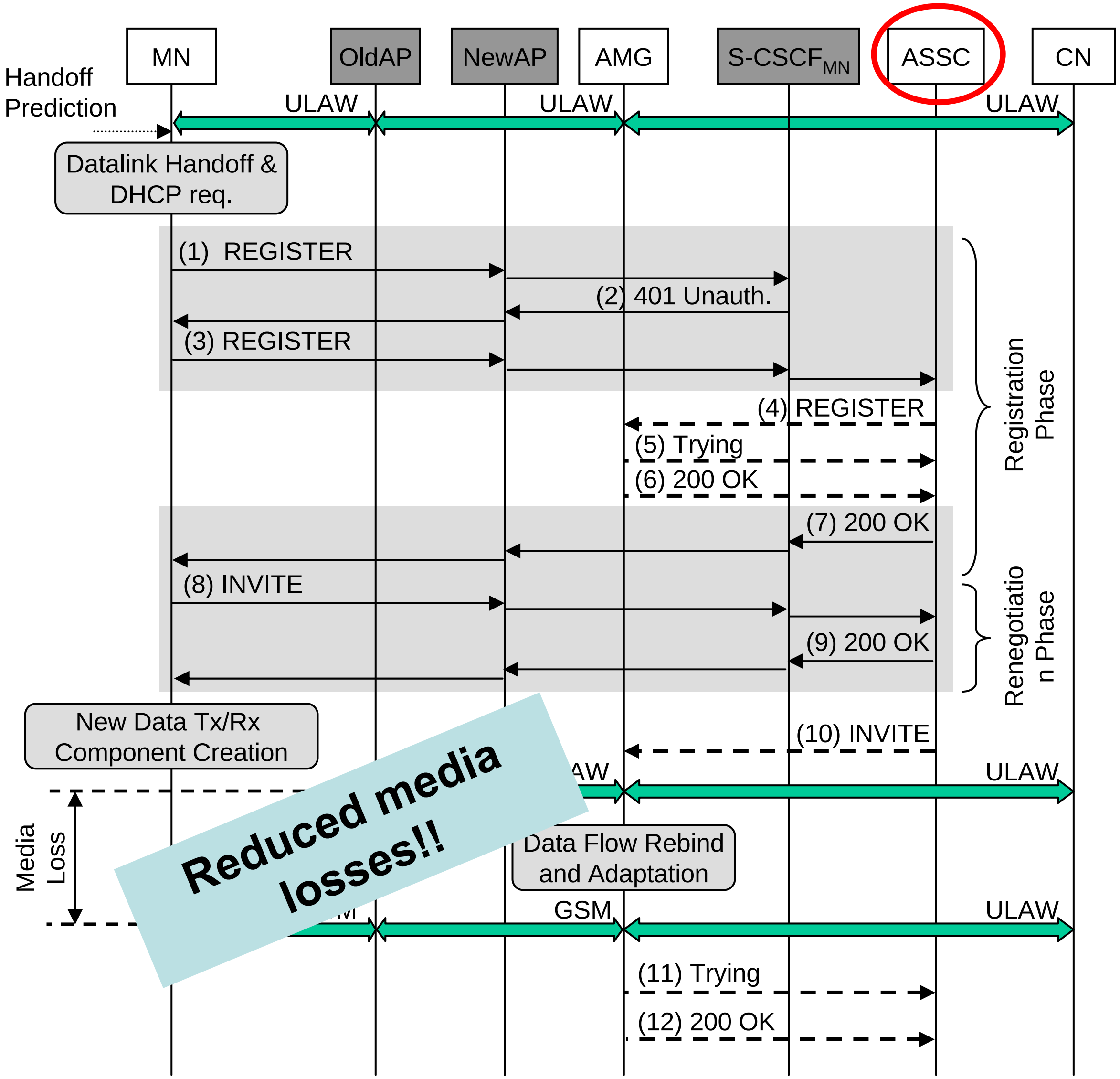
Specific characteristics/requirements of our mobility prediction solution:

- Wireless Internet-oriented
- Non-GPS-based
- Application-level & portable
- Coarse-grained cell precision
- Lightweight
- Completely decentralized

Main guideline: exploit ***client-side Received Signal Strength Indication (RSSI) monitoring*** and a simple Grey model to predict future RSSI values based on a ***very limited number (10)*** of past samples for each wireless AP

more details

Implementation Insights: AS for Service Continuity



1. VHP prediction proactively ***triggers handoff execution*** before IMS client detaches from old AP
2. (re-)REGISTER and (re-)INVITE signaling proceed ***over new AP*** (while data continue to flow over old wireless interface)
3. ASSC interacts with AMG to control data ***flow adaptation*** and ***rebind***

Implementation Insights: Adaptation Media Gateway

re-INVITE message

```
INVITE sip:alice@10.0.1.5:5070 SIP/2.0
Record-Route: <sip:mo@scscf.open-ims.test:6060;lr>,
              <sip:mo@pcscf.open-ims.test:4060;lr>
Call-ID: c2fa8bd0aff067d54f773562c15cba71@10.0.1.2
From: "bob" <sip:bob@open-ims.test>;tag=7762566
To: <sip:alice@open-ims.test>
…
Content-Type: application/sdp
CSeq: 300 INVITE
Content-Length: 132
v=0
o=bob@open-ims.test 0 0 IN IP4 10.0.1.4
s= -
c=IN IP4 10.0.1.4
t=0 0
m=audio 22224 RTP/AVP 3
b=AS:25
a=rtpmap:3 GSM/8000
```

SDP description

- AMG implementation is based on ***Asterisk***
- Asterisk can use several session control protocols (***SIP***, H.363, MGCP, …)
- ASSC-to-AMG communications based on SIP
  - Widely diffusion
  - Ease of integration

Asterisk configuration

```
[internal]
exten => bob,1,Dial(SIP/bob,60)
…
```

extensions.conf

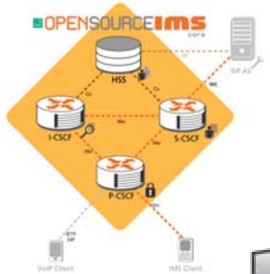
```
[general]
context=default
…
disallow=all
allow=gsm
allow=ulaw
canreinvite=no

[bob]
…
canreinvite=no
context=internal
```

sip.conf

- Asterisk configuration
  - **`extensions.conf`**: AMG serves any new call with "bob" extension by using SIP for session control
  - **`sip.conf`**: AMG allows gsm and ulaw audio encodings and ***`canreinvite`*** directive forces AMG to act as ***adaptation media gateway***

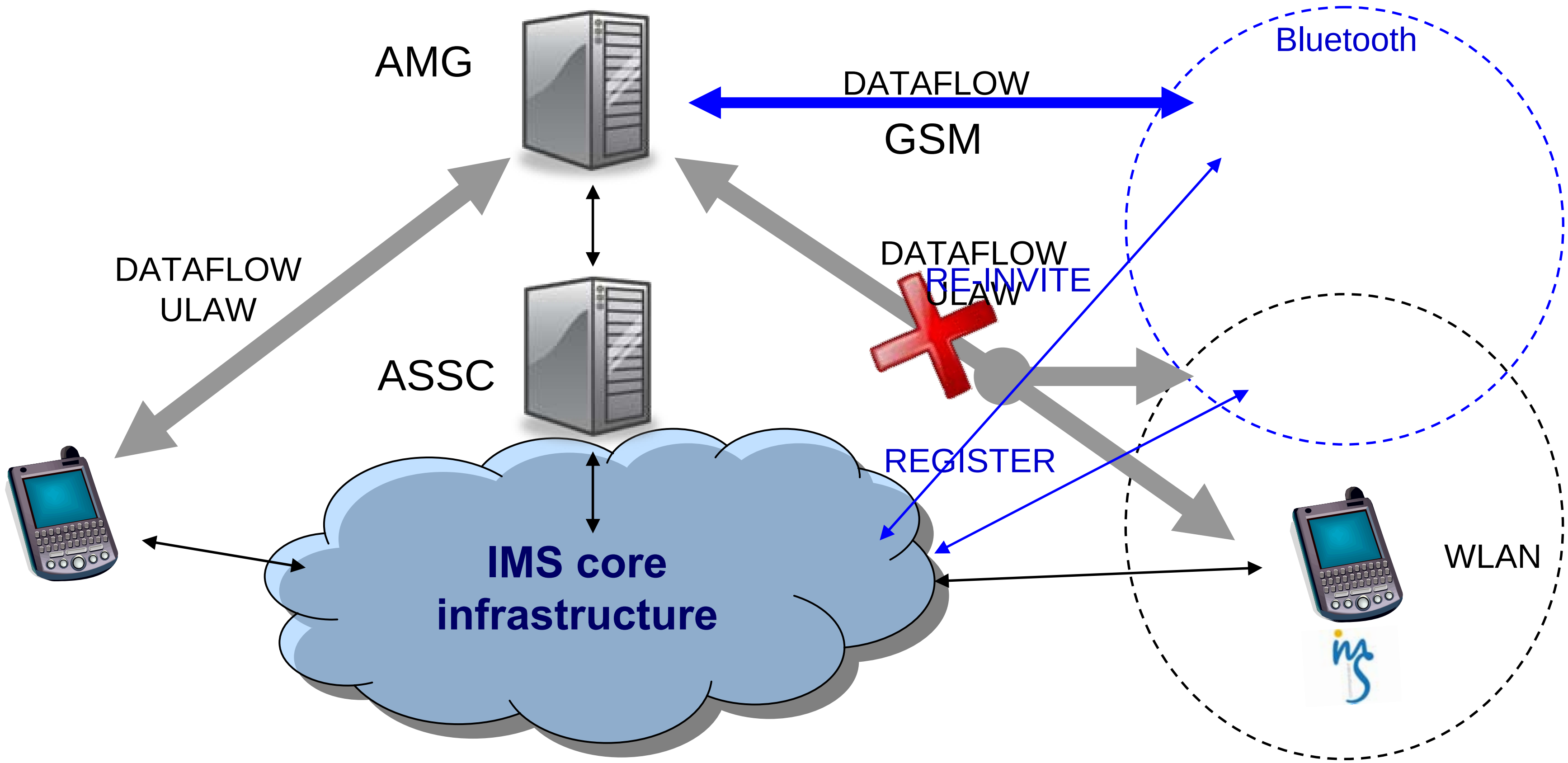
Implementation Details



ASSC

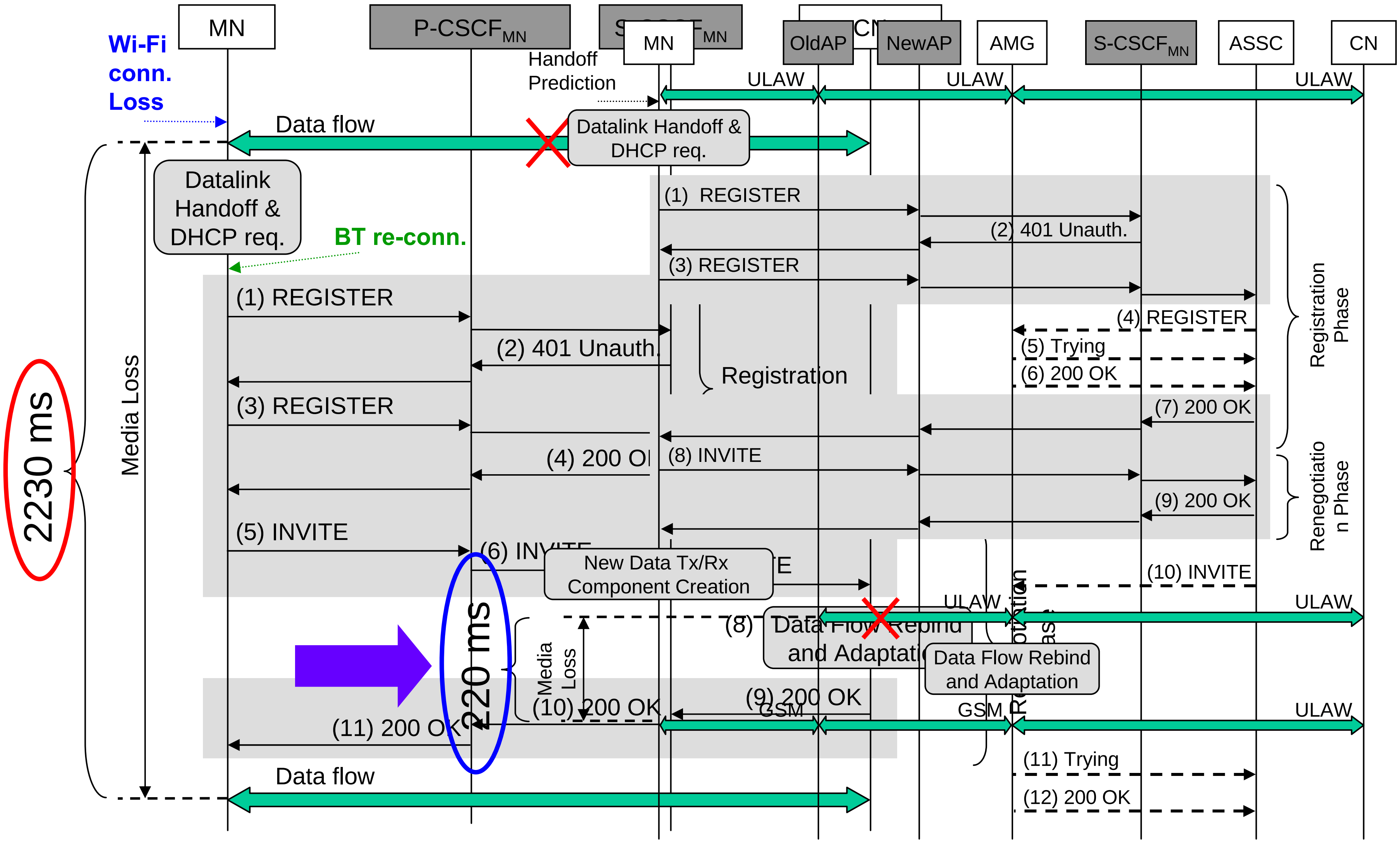
- IMS core components
  - OpenIMSCore (Fokus)
  - initial Filter Criteria (iFC) for IMS message re-routing
- ASSC
  - Java NIST JainSIP implementation of the SIP stack
  - OpenIMSCore properly configured to ASSC in the signaling path
- AMG
  - Asterisk telephony engine
  - High quality: ULAW/RTP audio, 50 frames/s, 64Kbps
  - Low quality: GSM/RTP audio, 50 frames/s, 13,2 Kbps
- IMS client
  - VHP: **`iwconfig`** and **`hcitool`** (Linux), NDIS (WIN)
  - VHP integration with IMS Communicator
- Deployment environment
  - Client: Asus laptops with IEEE 802.11b Cisco card and a Mopogo BT doungle
  - P-/I-/S-CSCF run on PCs: 2 CPUs 1,80GHz, 2048MB RAM, Linux Ubuntu
  - Wireless infrastructures:
    - Wi-Fi: Cisco Aironet 1100 AP
    - BT: Mopogo BT doungle, class 1, version 1.1

Experimental Testbed



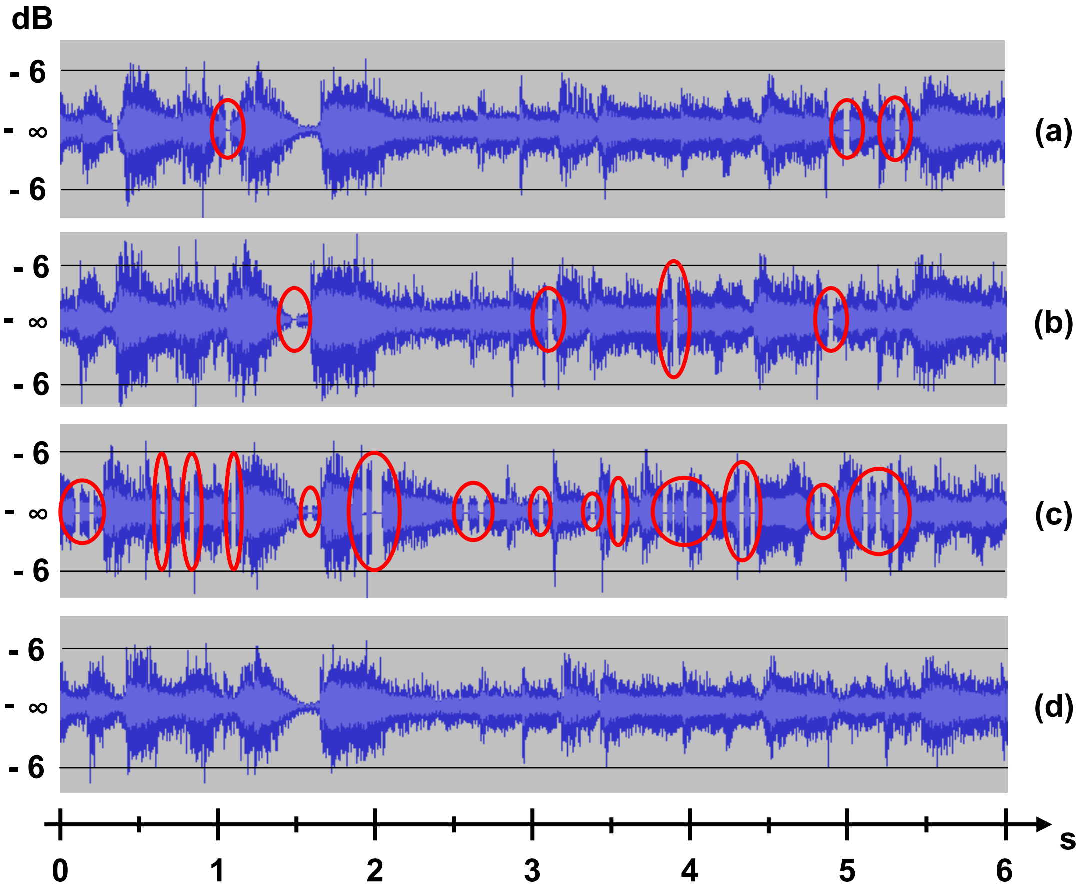
- **Handoff delay**: data loss period duration
- **Objective measurements**: audio waves collected at MN
- **Subjective measurements**: ITU Multiple Stimuli with Hidden Reference and Anchor (MUSHRA); different listening sessions submitted to 10 non-expert human operators by using the RateIt program

Experimental Results (1)



Experimental Results (2)

Objective evaluation
(received audio waves)



Subjective evaluation
(Misra score [0, 100])

Wi-Fi, ULAW: 75.3/100
→ **good**

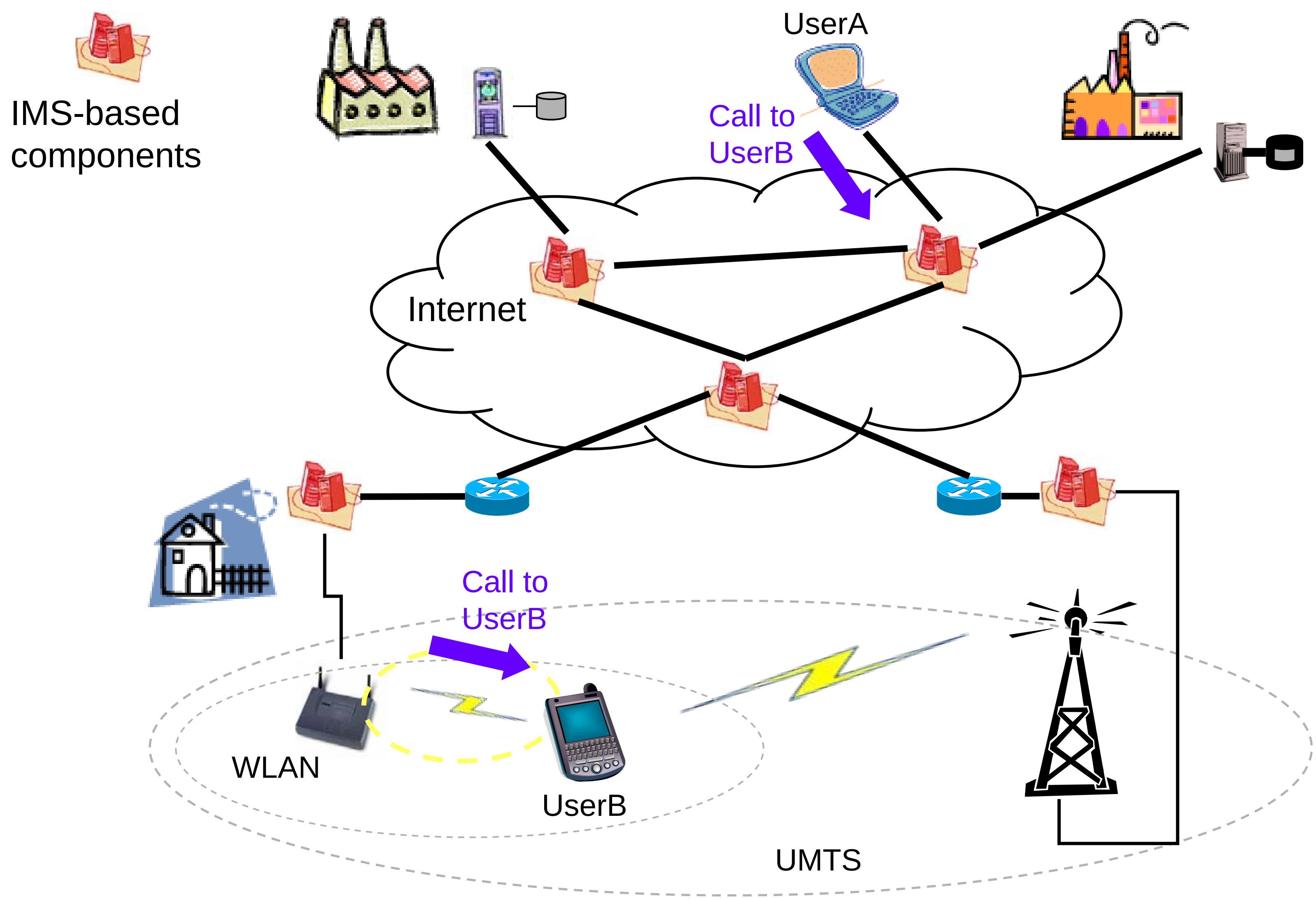
Bluetooth, ULAW, w/o background traffic: 72.3/100
→ **good**

Bluetooth, ULAW, with background traffic: 5.4/100
→ **bad**

Bluetooth, GSM, with background traffic: 64.3/100
→ **good**

- Conclusions
  - Suitability of ***application-level approach*** to extend the standard IMS infrastructure for session continuity
  - Dynamic content adaptation techniques permit to grant high user satisfaction even in the challenging case of vertical handoff
- Ongoing work
  - Additional objective measures of ***quality degradations*** experienced w/out multimedia adaptation at AMG
  - Design and deployment of other forms of proactive handoff management, and ASSC scalability assessment

IHMAS Power Management



Context-aware power management ***middleware***

- **updates** low level parameters (wireless communications availability, battery level, …)

  → ***wireless access prediction and mobile node energy monitoring***

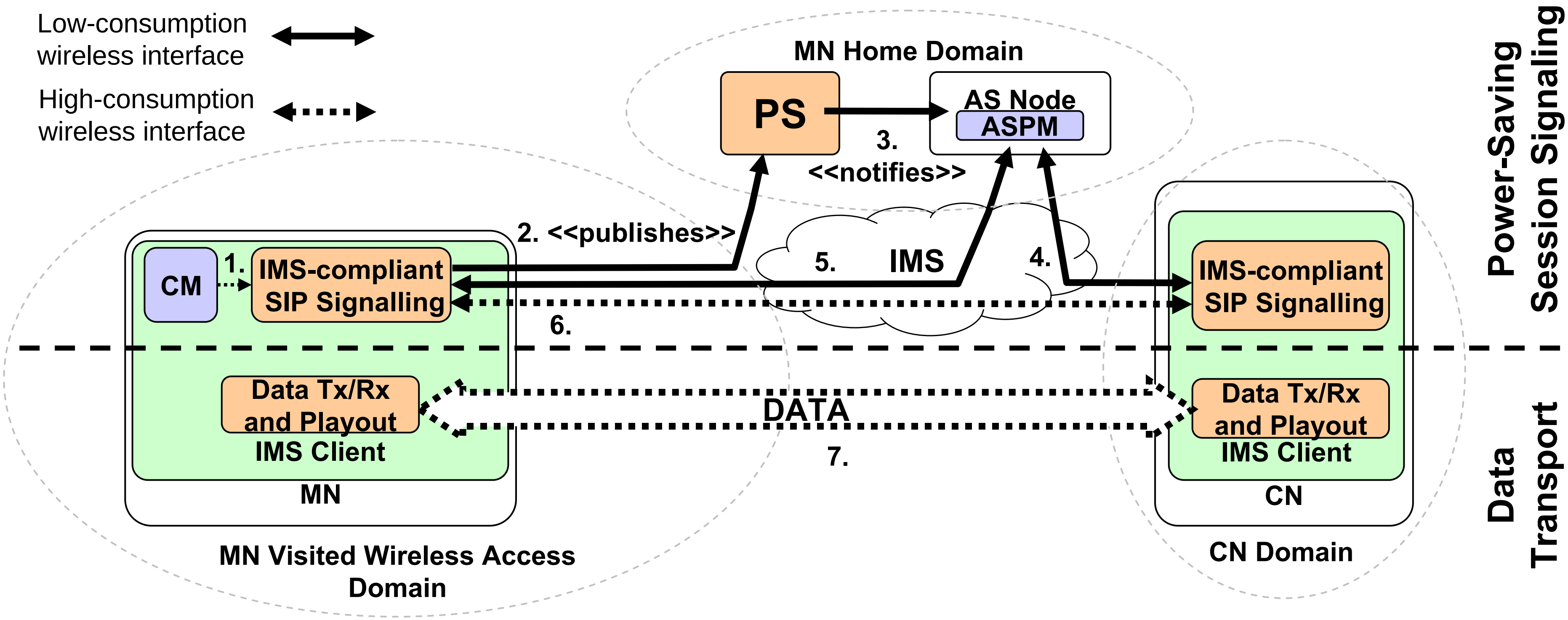
- **executes** application-level specific **energy-saving decisions** and **session signaling actions**

  → ***dynamic wireless interface switch on and automatic session re-direction/handoff***

- **integrates** seamlessly with existing infrastructures

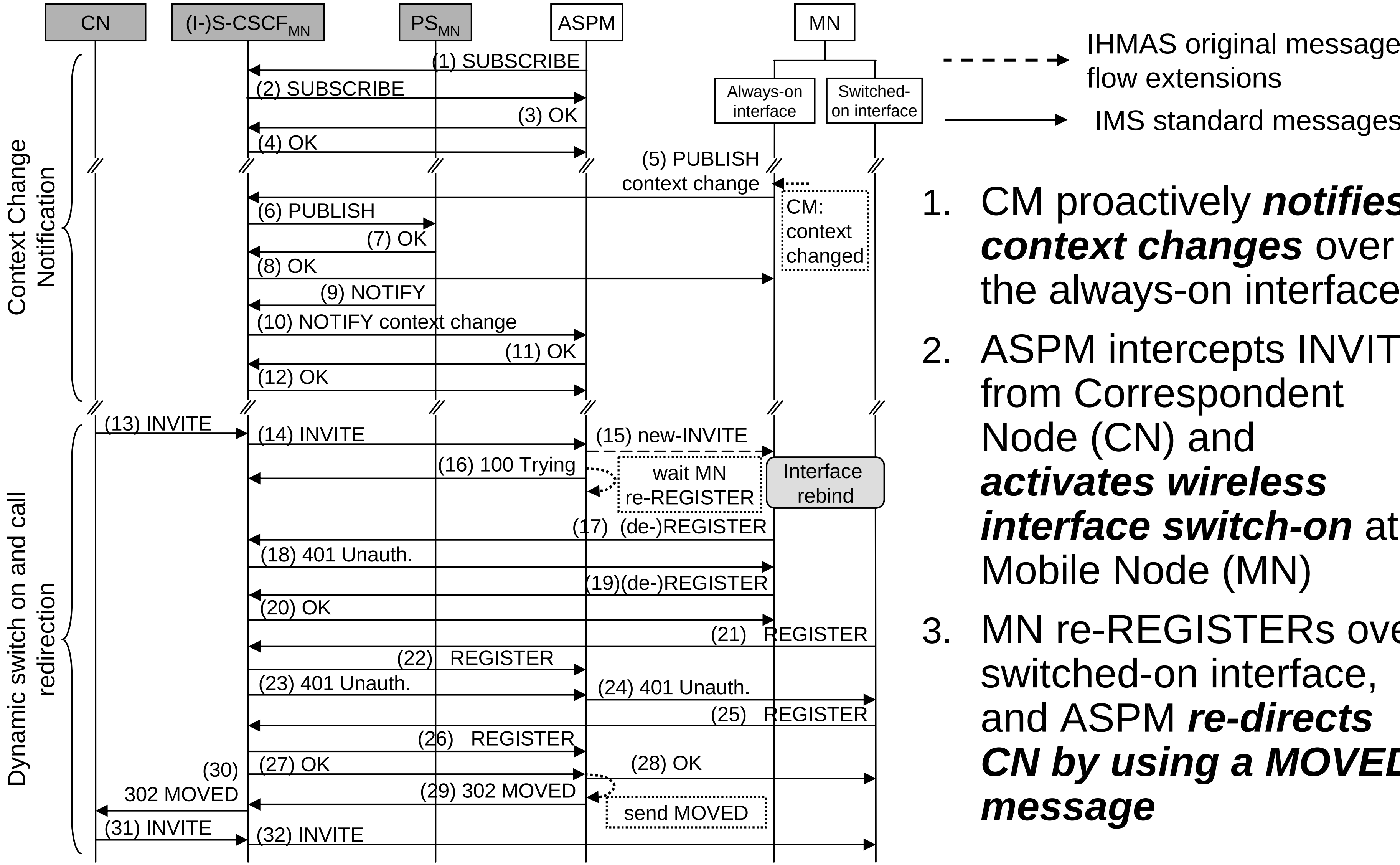
  → ***full compliancy with IMS standard***

IHMAS Power Management Facility: Distributed Architecture



- Context Monitor – ***CM*** (one for client): implements lightweight and completely decentralized context monitoring via local access to client wireless devices
- AS for Power Management – ***ASPM*** (one for IMS domain): realizes our IMS energy-saving optimization
- IMS PS – ***PS*** (one for access locality): facilitates CM-ASPM interactions

IHMAS Power Management Facility: Modified Invitation Protocol



1. CM proactively ***notifies context changes*** over the always-on interface
2. ASPM intercepts INVITE from Correspondent Node (CN) and ***activates wireless interface switch-on*** at Mobile Node (MN)
3. MN re-REGISTERs over switched-on interface, and ASPM ***re-directs CN by using a MOVED message***

Implementation Insights: AS for Power Management

```
private void processInvite(Request request) {
1.  SessionDescription sdp =
      sipUtils.getSessionDescription(request);
      sd=addPowerManagementAttribute(request, sd);
      request.removeContent();
2.    try {
        request.setContent(sd,
        headerFactory.
          createContentTypeHeader("application","sdp"));
      } catch (ParseException e) { e.printStackTrace(); }
      try {
3.      sipProvider.sendRequest(request);
      } catch (SipException e) { e.printStackTrace(); }
}
```

- ASPM implementation is based on ***JAIN SIP stack***
- On INVITE message, ASPM:
  1. Extracts Session Description Protocol (SDP) part of the message
  2. Adds in the optional field ("a:" field) the MAC of the wireless interface to switch on
  3. Sends it to MN

```
INVITE sip:alice@open-ims.test SIP/2.0
…
Content-Type: application/sdp
Content-Length: 414

v=0
o=- 0 0 IN IP4 192.168.3.11
s=IMS Call
c=IN IP4 192.168.3.11
t=0 0
m=audio 10281 RTP/AVP 3 0 14 101
b=AS:64
a=rtpmap:3 GSM/8000
a=rtpmap:0 PCMU/8000
a=rtpmap:14 MPA/90000
a=rtpmap:101 telephone-event/8000
a=fmtp:101 0-11
a=curr:qos local none
a=curr:qos remote none
a=des:qos mandatory local sendrecv
a=des:qos mandatory remote sendrecv
a=switchoninterface:00:04:23:5E:48:DE 192.168.125.2
```

- ***Modified INVITE*** message
  - SDP part of the INVITE message as modified by ASPM
  - **Note our application parameter `a:…`** field at the end of the message

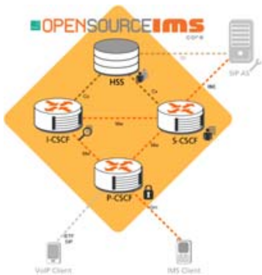
Implementation Insights: IMS Client

```
void ims_process_incoming_invite(eXosip_event *je)
{ …
  sdp_message_t * sdp_message;
  eXosip_lock();
  sdp_message=eXosip_get_sdp_info(je->request);
  eXosip_unlock();
  switchOnAddress=extractPowerManAttribute(sdp_message);
  if(newInvite) ims_send_de_register();
  else { … /* standard session invite management */ }
}

void ims_send_re_register()
{
int port=5060, pid, status;
pid=fork();
if(pid==0) {  // child
  if(!is_bye) { execl("../scripts/switchOnInterface.sh",
                "switchOnInterface.sh", switchOnAddress, (char *)0 ); }
  else { execl("../scripts/switchOffInterface.sh",
         "switchOffInterface.sh", switchOnAddress, (char *)0 );  }
} else {      // parent
  wait(&status);
  if(!is_bye) { while( eXosip_listen_addr(IPPROTO_UDP, switchOnAddress,
                            port, AF_INET, 0) != 0 ) port++; }
  else { while( eXosip_listen_addr(IPPROTO_UDP, alwaysOnAddress,
                            port, AF_INET, 0) != 0 ) port++; }
  ims_send_register();
}
```

- Based on ***UCT IMS Client***
- New-INVITE processing
  - ***Extracts*** from the "a:…" field ***the MAC of the wireless interface to switch on***
  - Sends de-REGISTER
- Re-registration
  - ***Switches on the wireless interface***
  - ***Sends a REGISTER*** over the switched-on wireless interface

Implementation Details



- IMS core components
  - OpenIMSCore (Fokus)
  - initial Filter Criteria (iFC) for IMS message re-routing

ASPM

- ASPM
  - Java NIST JainSIP implementation of the SIP stack
  - OpenIMSCore properly configured to interpose ASPM in the signaling path

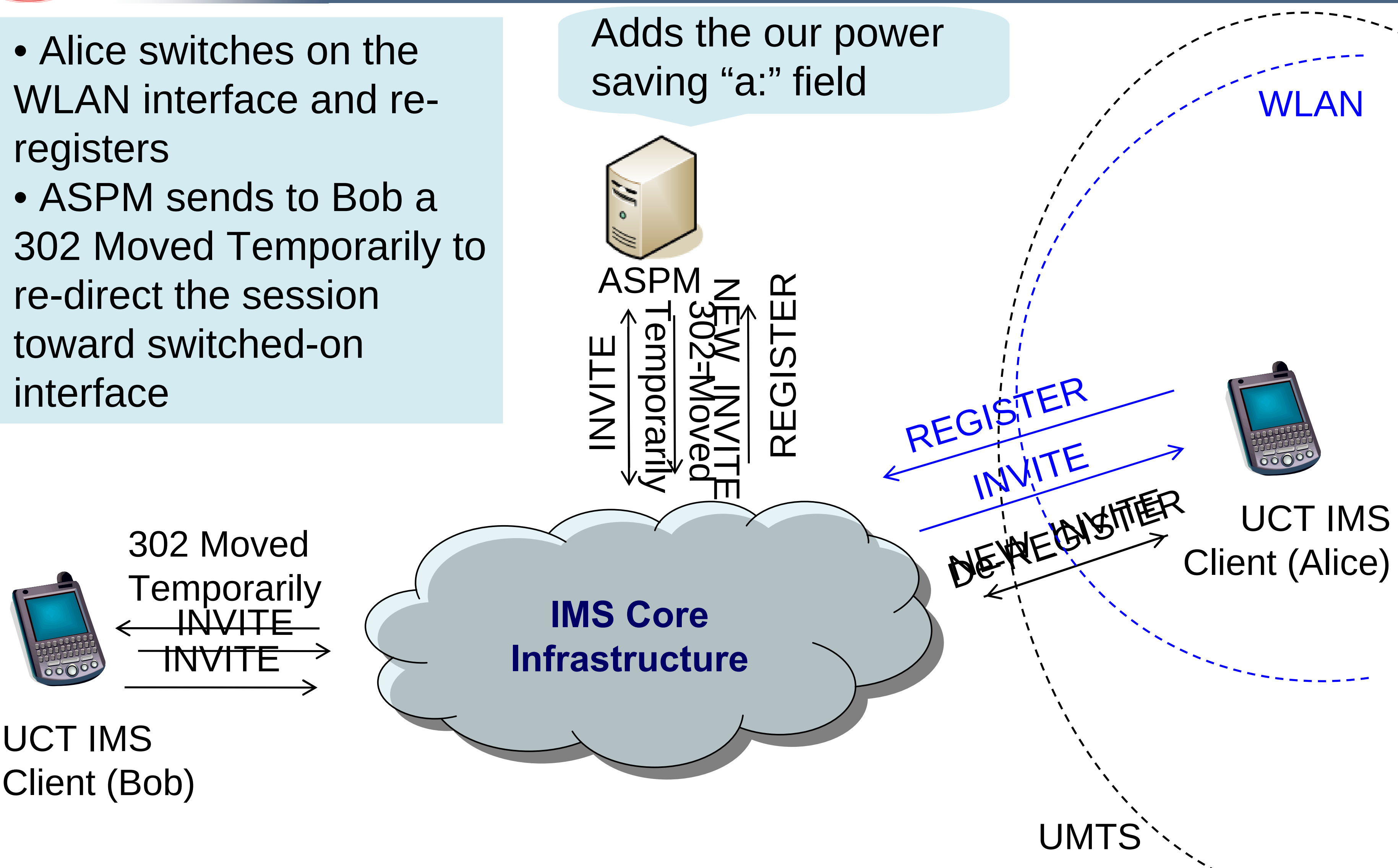
UCT IMS Client

- University of Cape Town (UCT) IMS Client
  - CM: **`iwconfig`** and **`hcitool`** (Linux), NDIS (WIN)
  - CM integration with UCT IMS Client

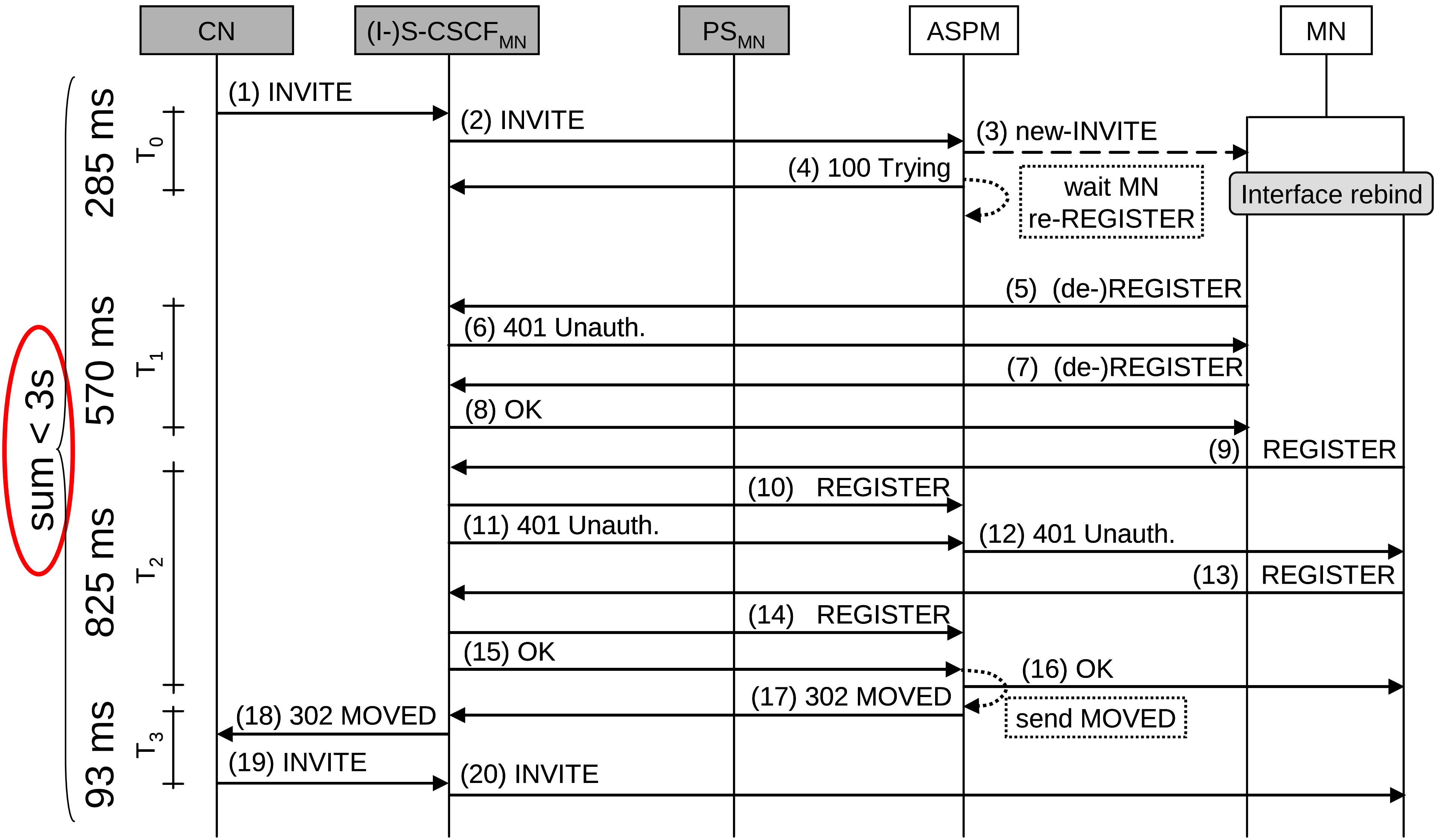
- Deployment environment
  - Client: Linux laptops with 3G UMTS adaptor and IEEE 802.11b Cisco card
  - P-/I-/S-CSCF run on PCs: 2 CPUs 1,80GHz, 2048MB RAM, Linux Ubuntu
  - Wireless infrastructures:
    - Wi-Fi: Cisco Aironet 1100 AP

Experimental testbed

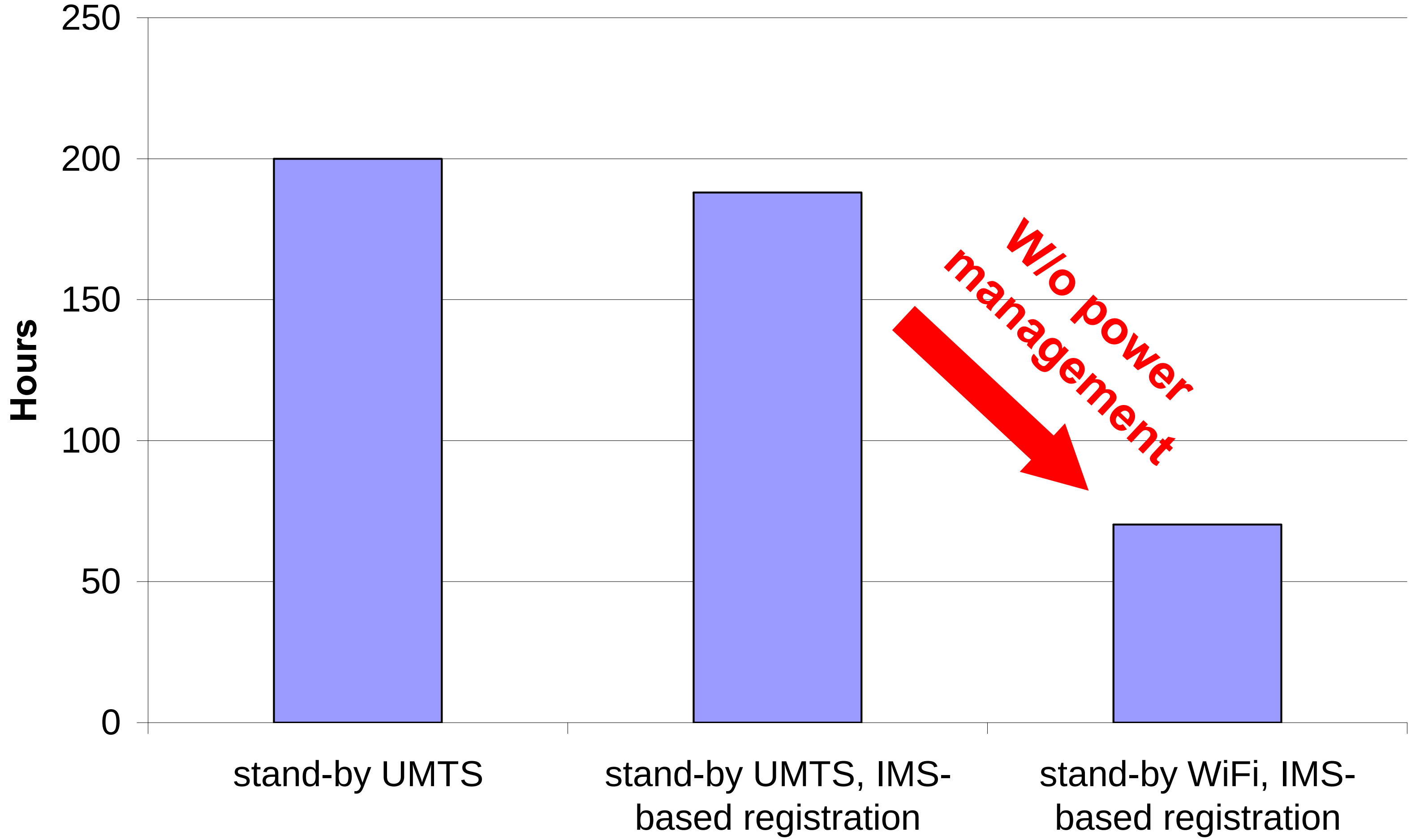
- Alice switches on the WLAN interface and re-registers
- ASPM sends to Bob a 302 Moved Temporarily to re-direct the session toward switched-on interface



Experimental Results (1)

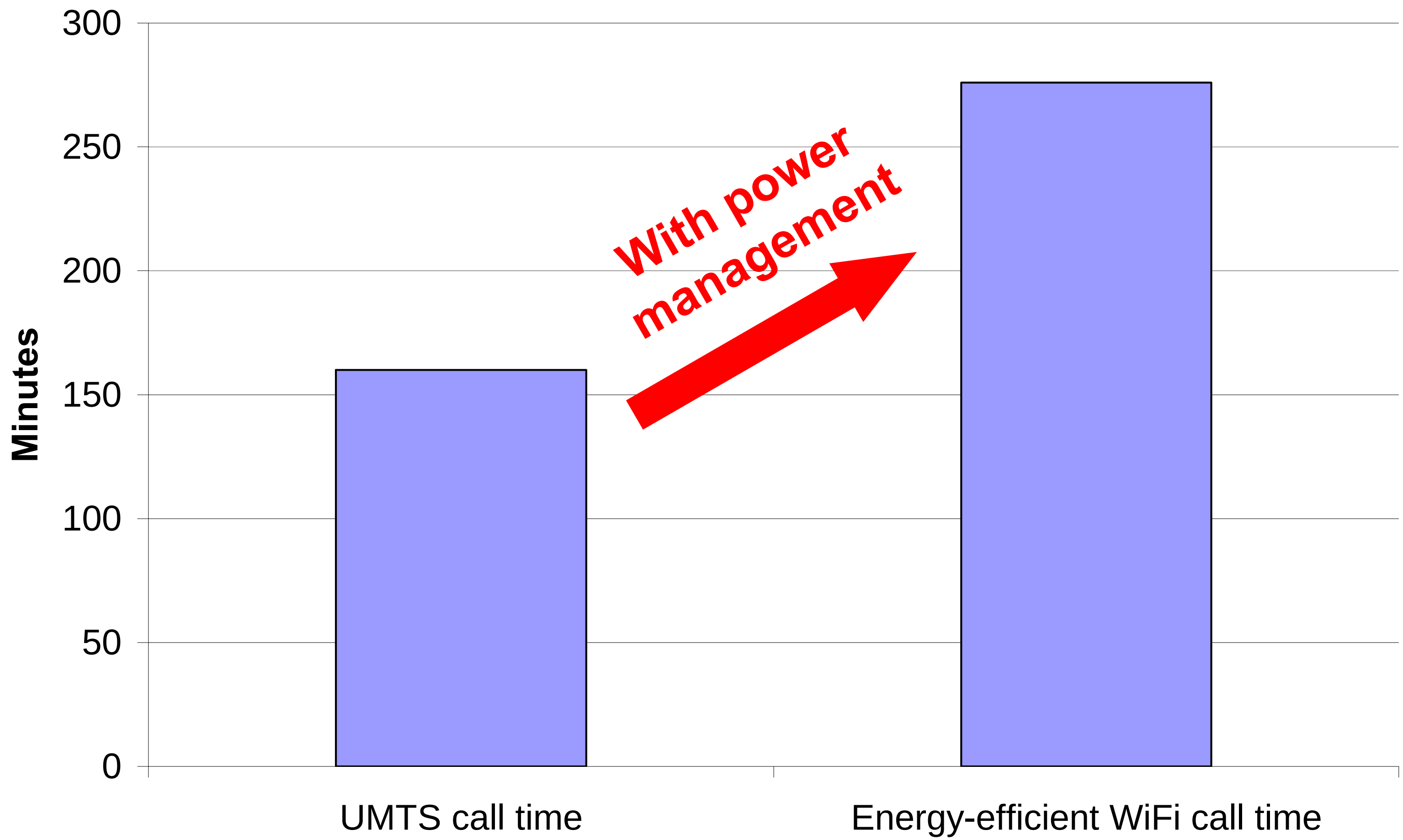


Experimental Results (2): Stand-by time



- Analitical results evaluated for N95
  - Battery: 950mAH and charged at 3.7V
  - WiFi avarage additional consumption (always-on): 0.05W

Experimental Results (3): Call time



- Energy-efficient WiFi call time is longer than the talk time duration specified by Nokia for UMTS.

IHMAS Power Management: Conclusions and ongoing work

- Conclusions
  - Energy-saving techniques ***relevantly increase battery lifetime*** when using high-consumption and low-cost wireless interfaces
  - ***Session invitation delays*** introduced by the IHMAS facility for power management are ***compatible even with strict VoIP call requirements***

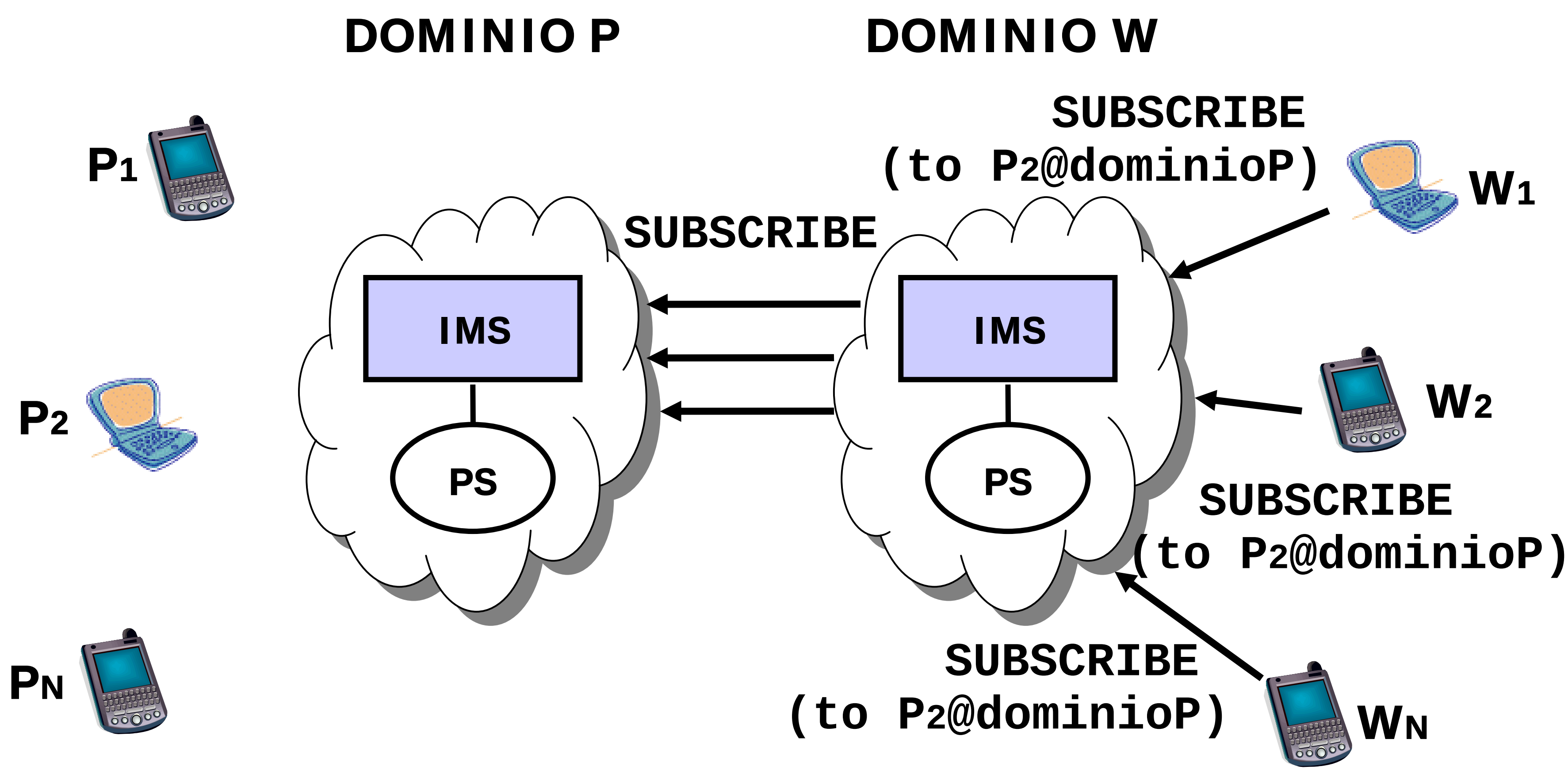
- Ongoing work
  - J2ME version of CM and IMS client, tailored to any consumer device hosting a J2ME platform
  - Extensive measurements of energy consumption in real and wide-scale deployment environment

IHMAS PS scalability optimizations

P: presentity **PS**: Presence Server

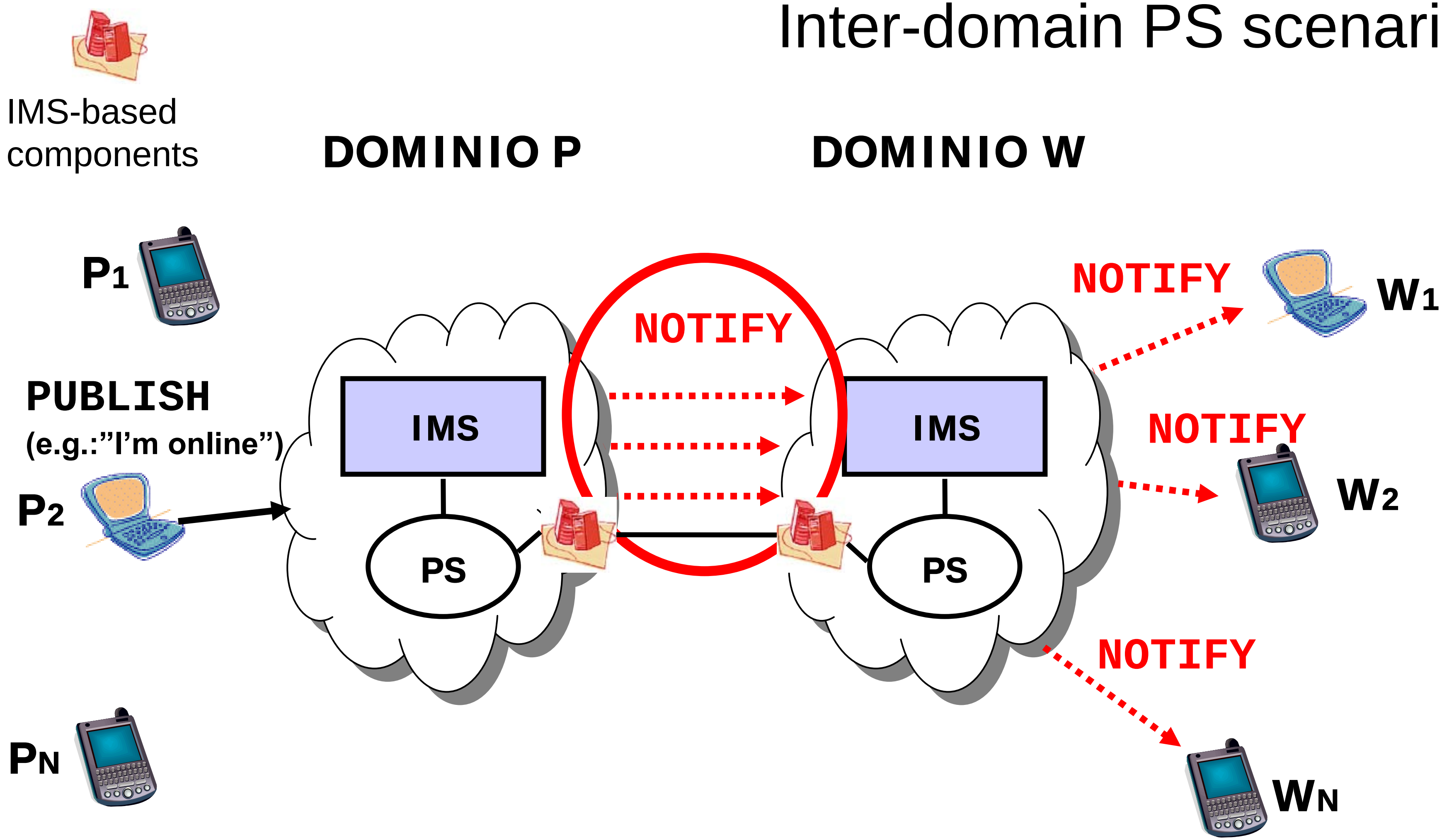
W: watcher

Inter-domain PS scenario



IHMAS PS scalability optimizations

Inter-domain PS scenario



Problem: high number of inter-domain PS messages

IHMAS PS scalability optimizations

IHMAS IMS-based PS solution

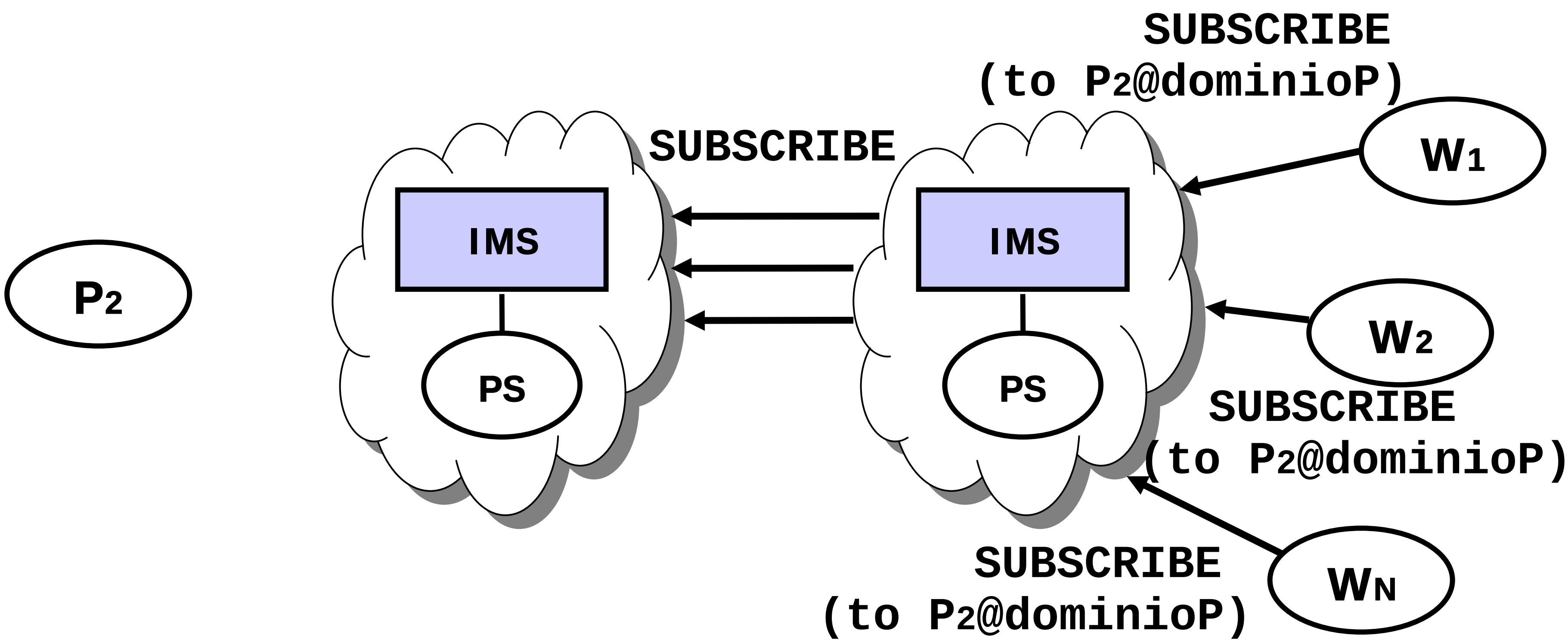
- **extends IMS PS** to support inter-domain PS optimizations (diminish the number of inter-domain NOTIFY transmissions)

  → ***novel PS inter-domain optimization module for NOTIFY message parsing and inter-domain routing***
- **supports** mobile clients and **service differentiation** (gold, silver, copper, …)

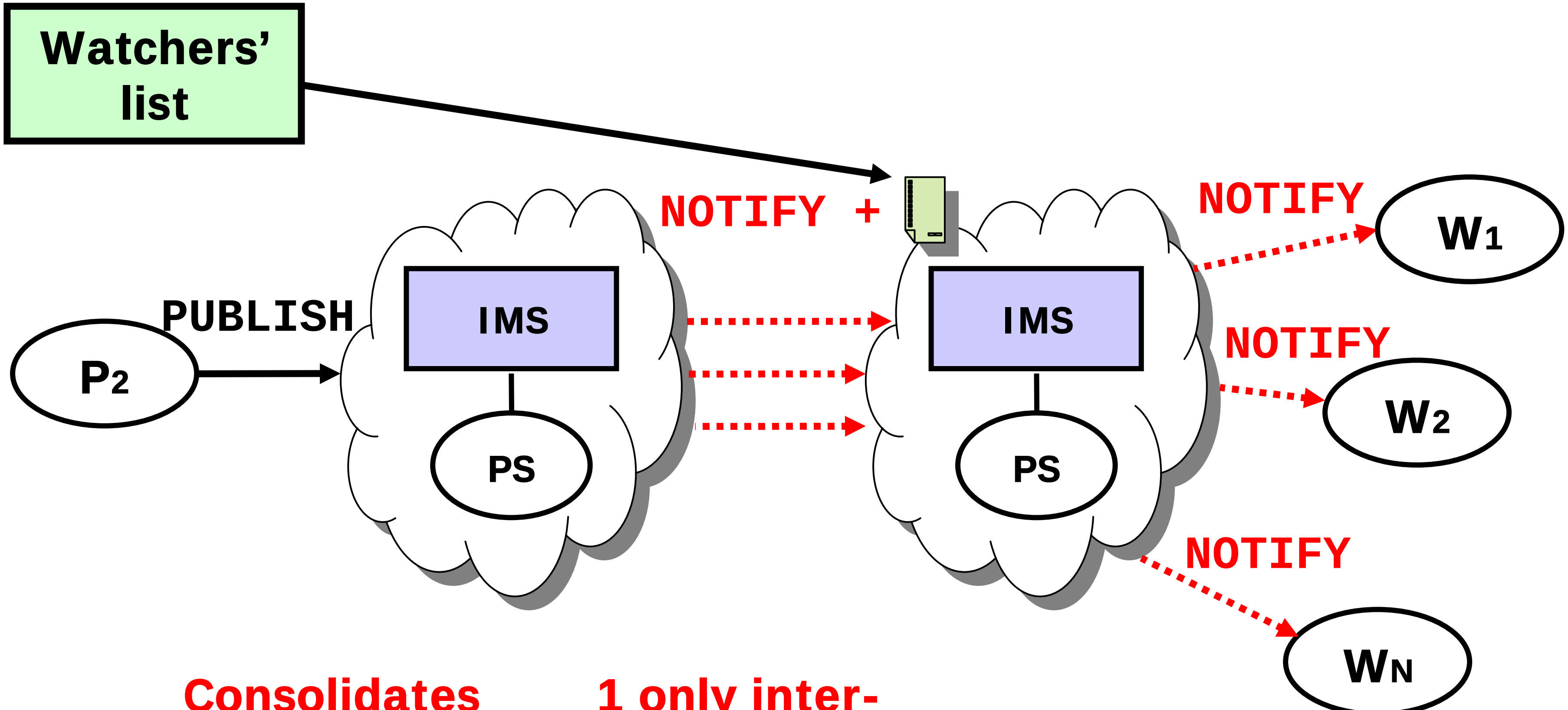
  → ***local PS message buffering at mobile device and differentiated service management at PS***
- **integrates** seamlessly with existing infrastructures

  → ***full compliancy with IMS standard***

"Several Watchers subscribed to one Presentity"



Optimizations towards scalability: common NOTIFY (2)



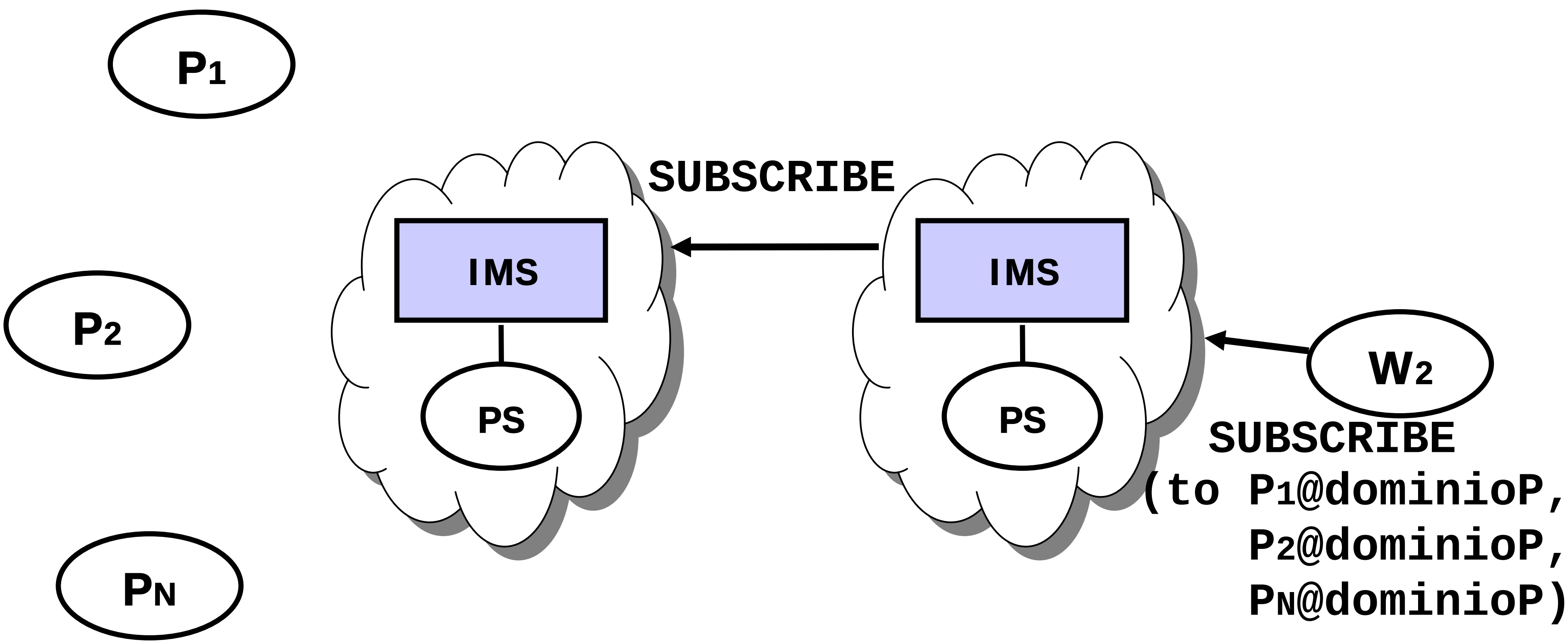
Consolidates NOTIFY messages at *Presentity's* domain

1 only inter-domain NOTIFY message

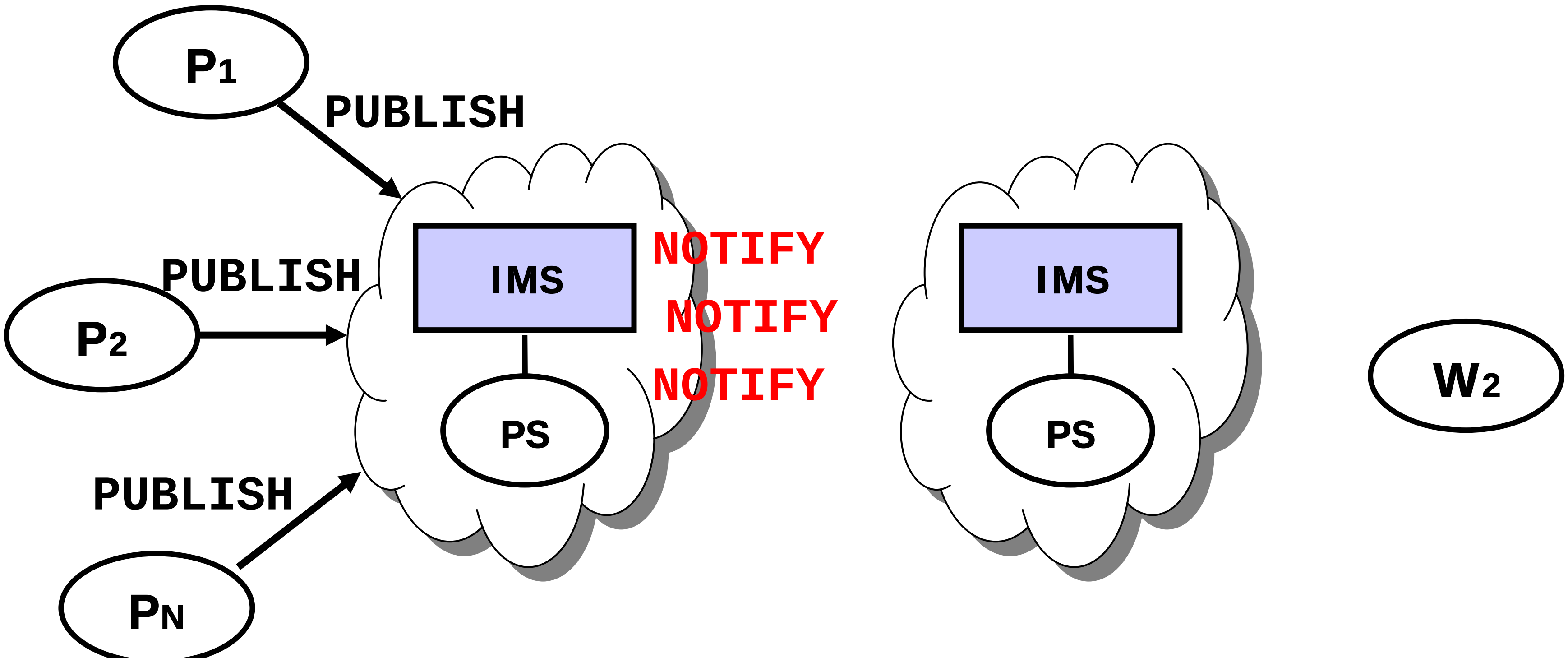
NOTIFY messages creation at Watchers's domain

Optimizations towards scalability: batched NOTIFY

"One single Watcher subscribed for multiple Presentities"

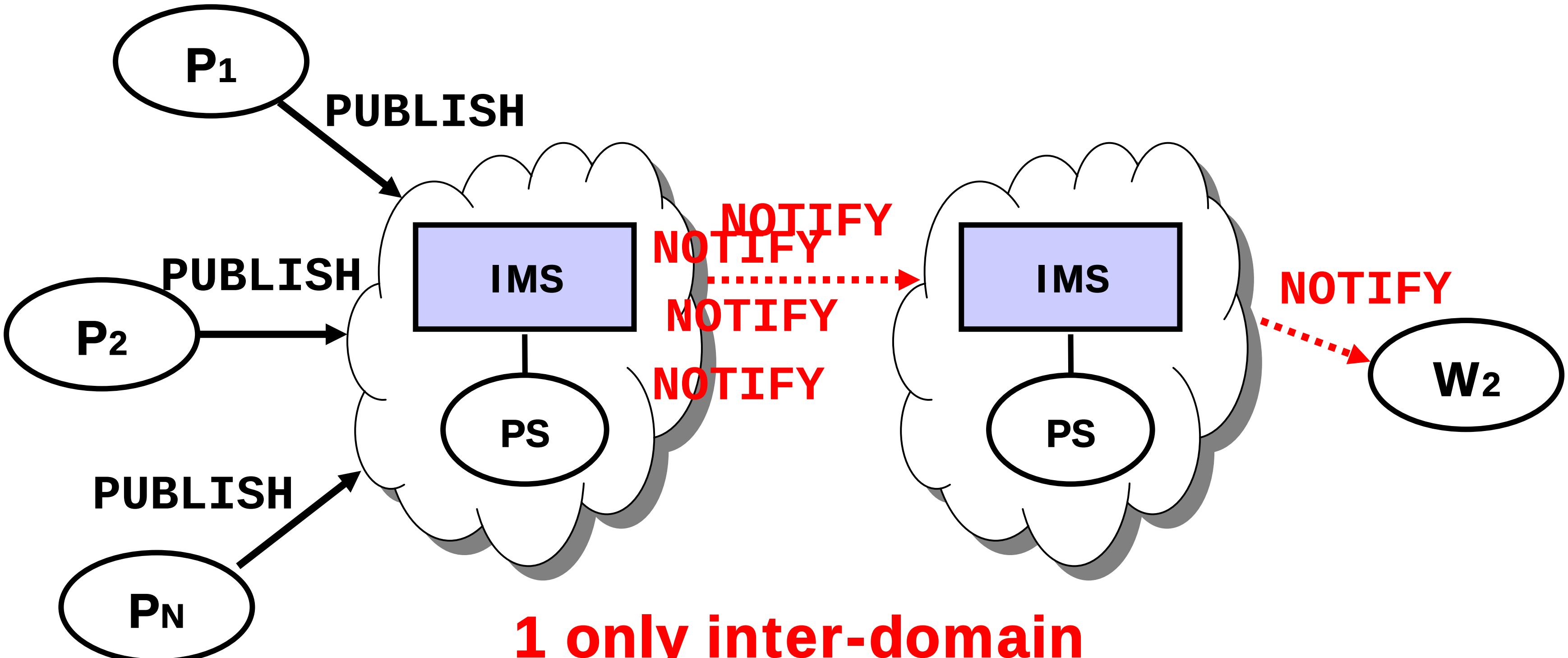


Optimizations towards scalability: batched NOTIFY (2)



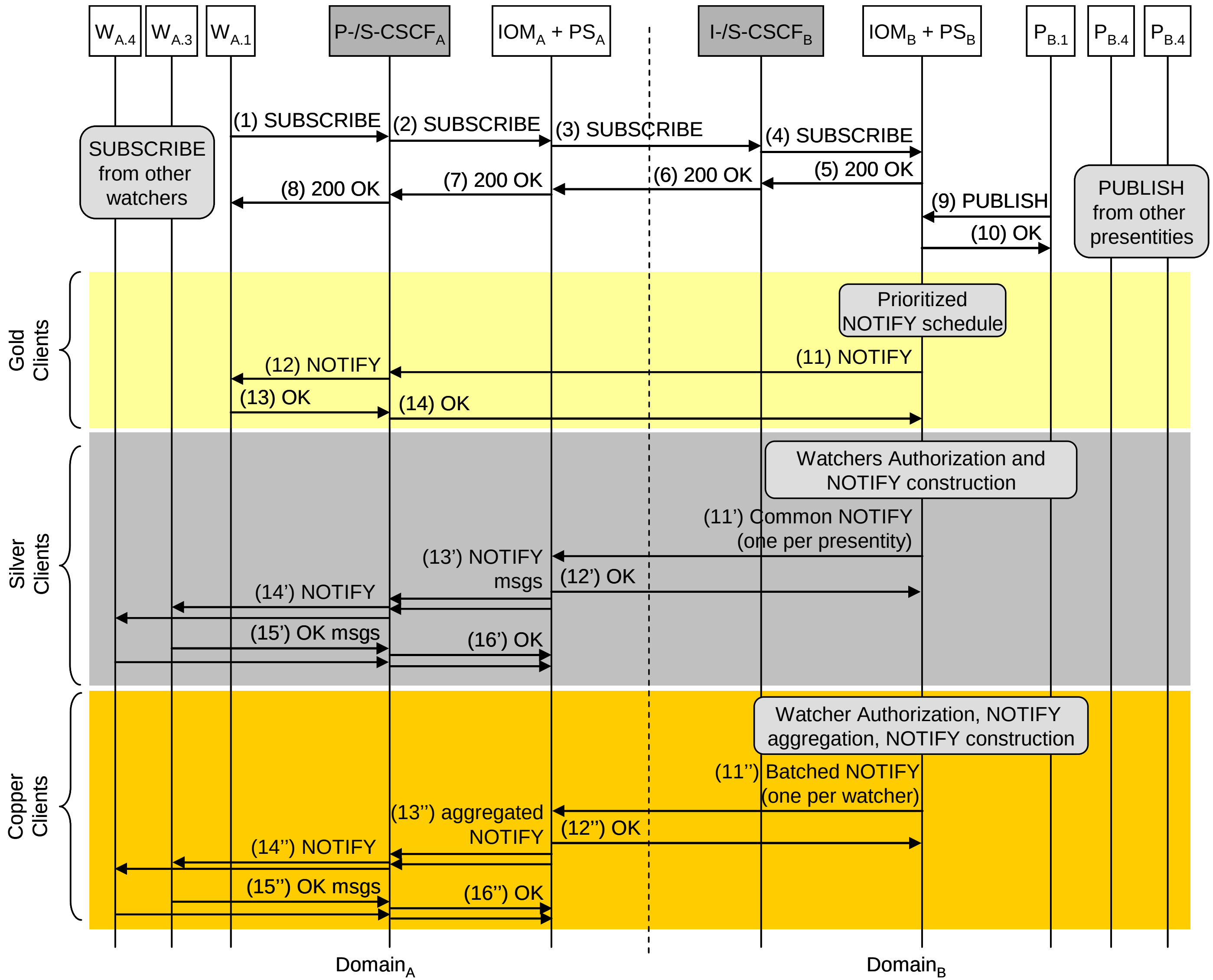
Time-based (periodic) NOTIFY message batching

Optimizations towards scalability: batched NOTIFY (3)



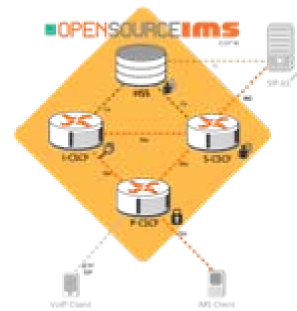
1 only inter-domain NOTIFY message

IHMAS PS scalability: PS protocol enhancements

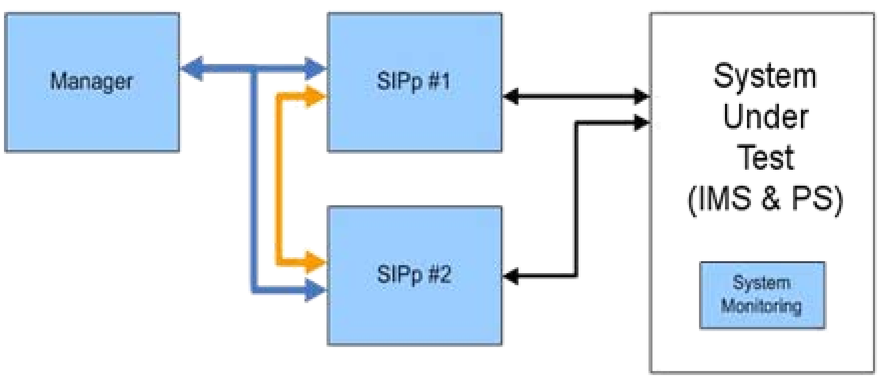


Implementation Details

- IMS infrastructure → **Open IMS Core**

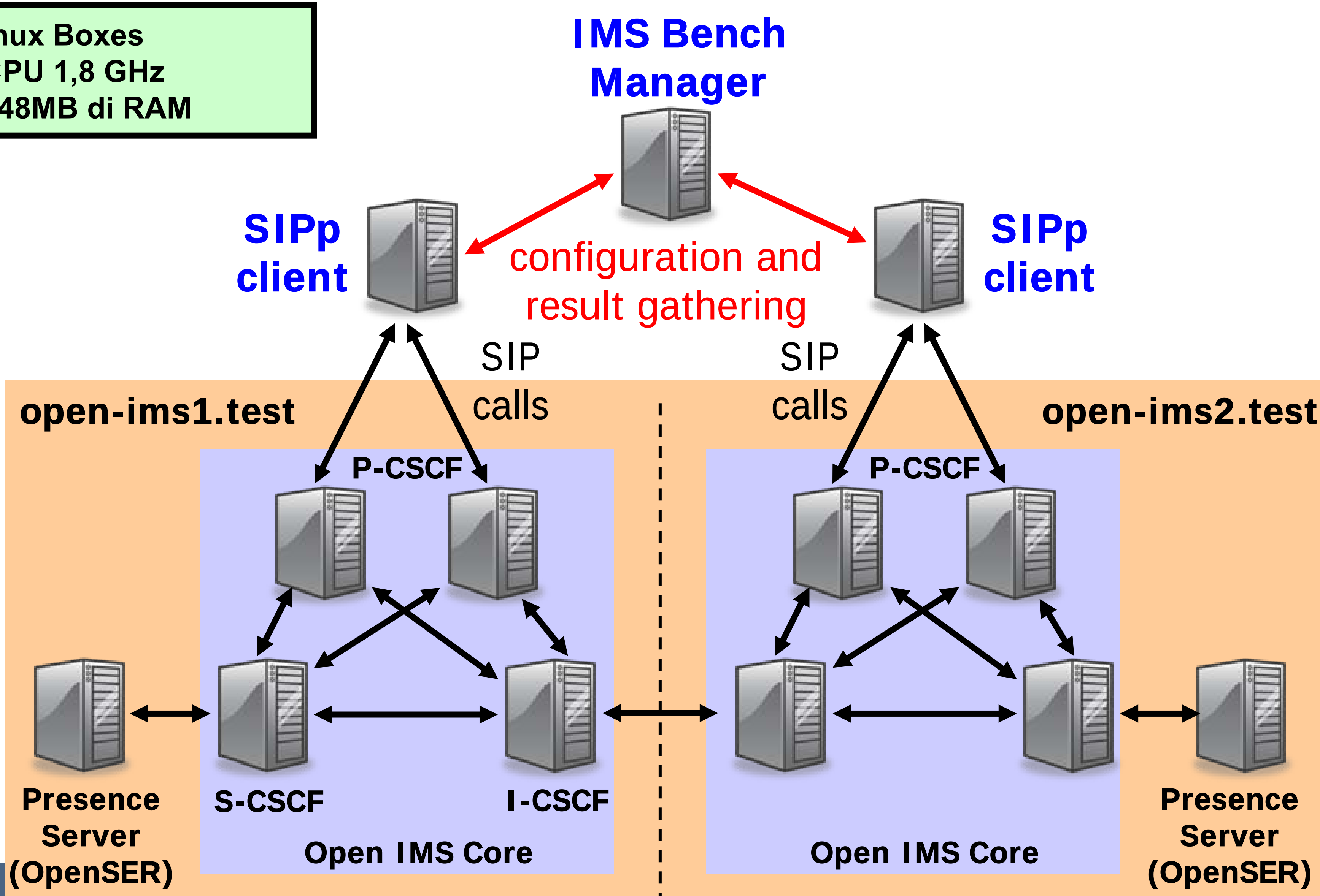


- Presence Server → **OpenSER**
- SIP traffic generation → **IMS Bench SIPp**

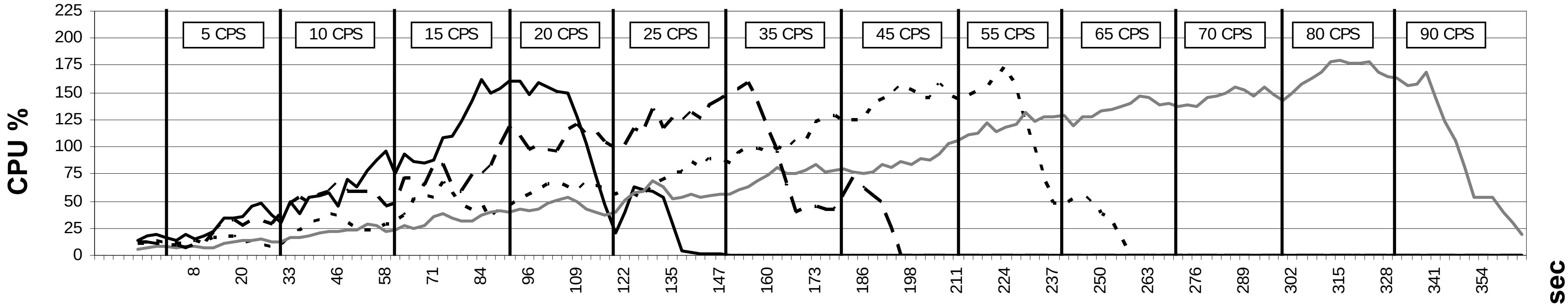


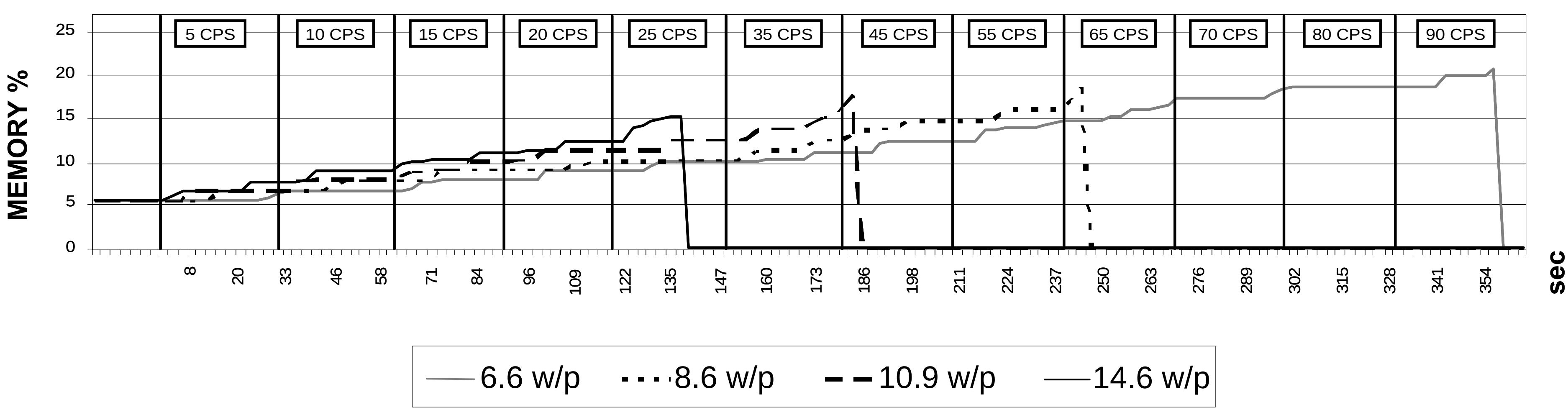
Experimental testbed

Linux Boxes
2CPU 1,8 GHz
2048MB di RAM

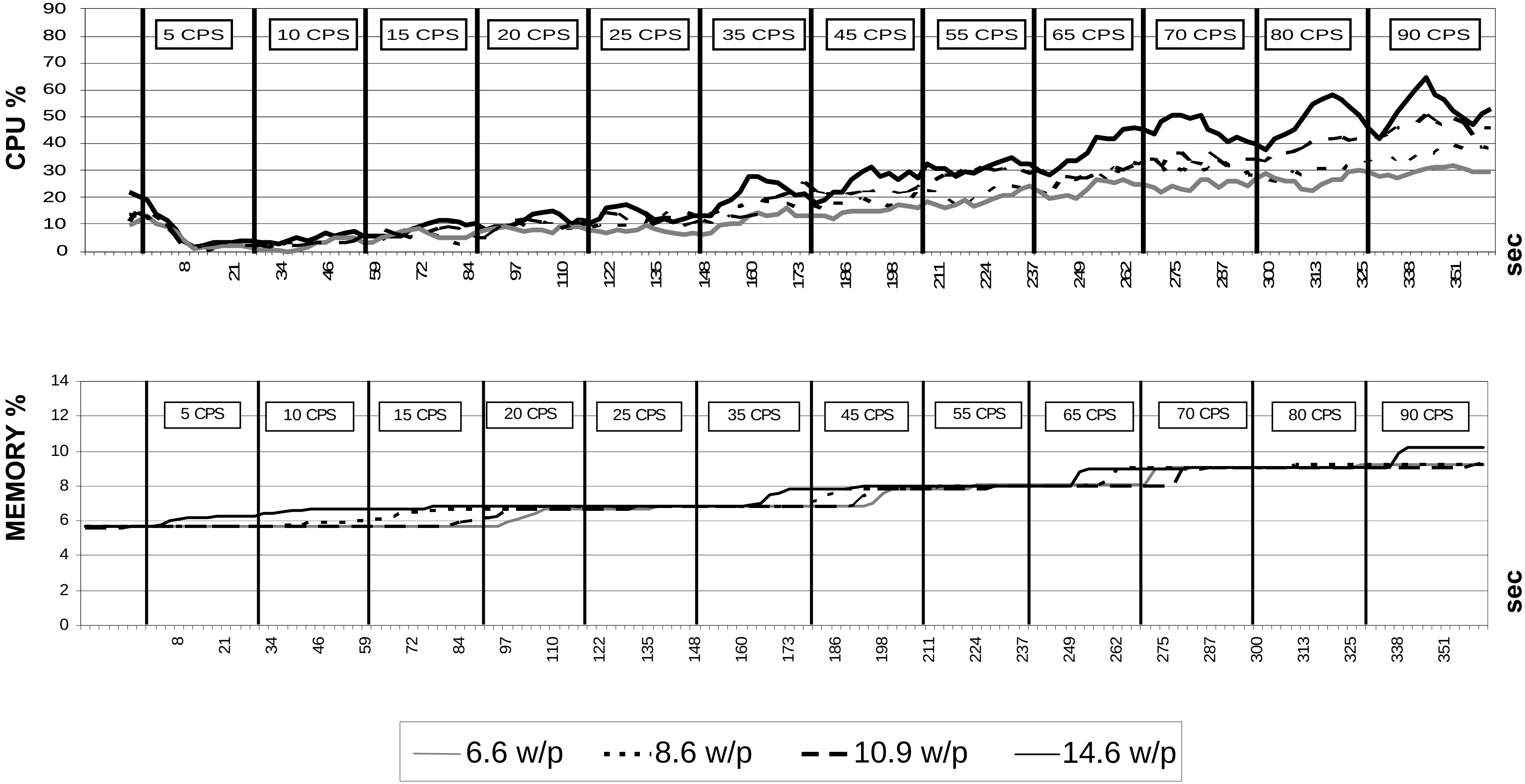


Experimental results:
w/out IHMAS optimizations

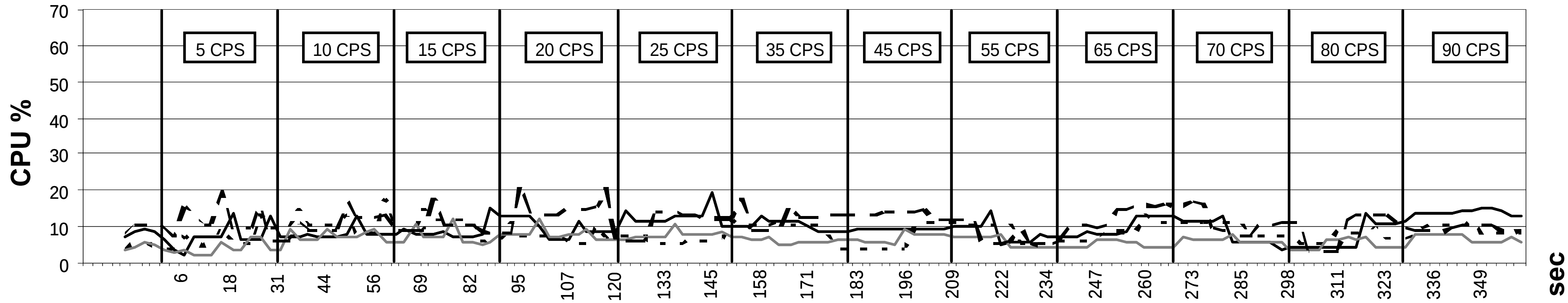


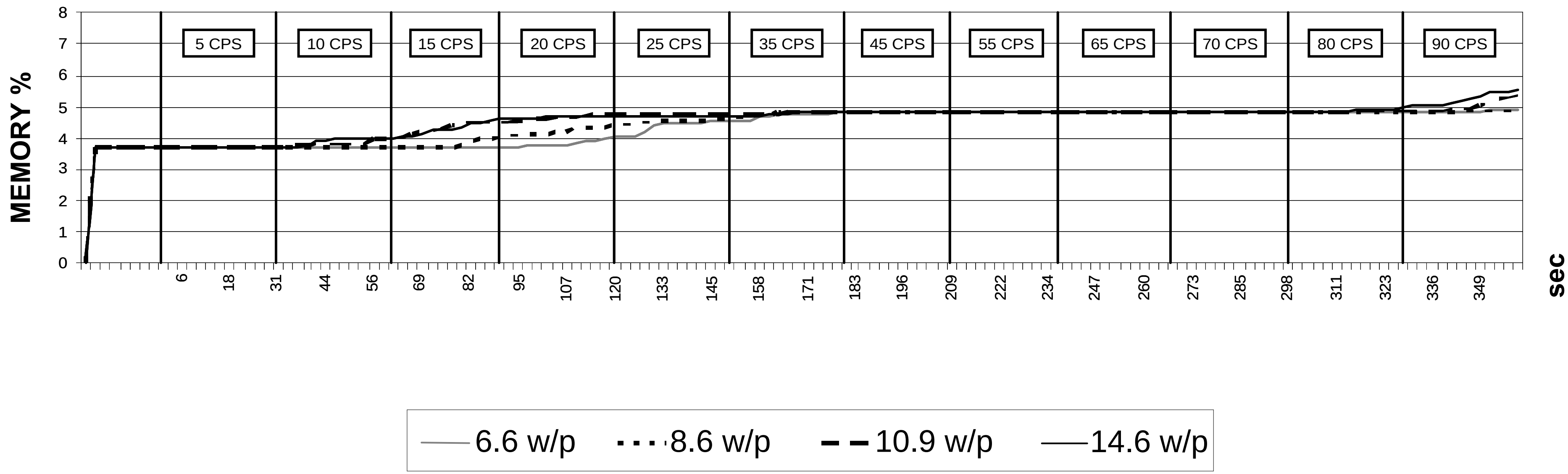


Experimental results:
with IHMAS common NOTIFY

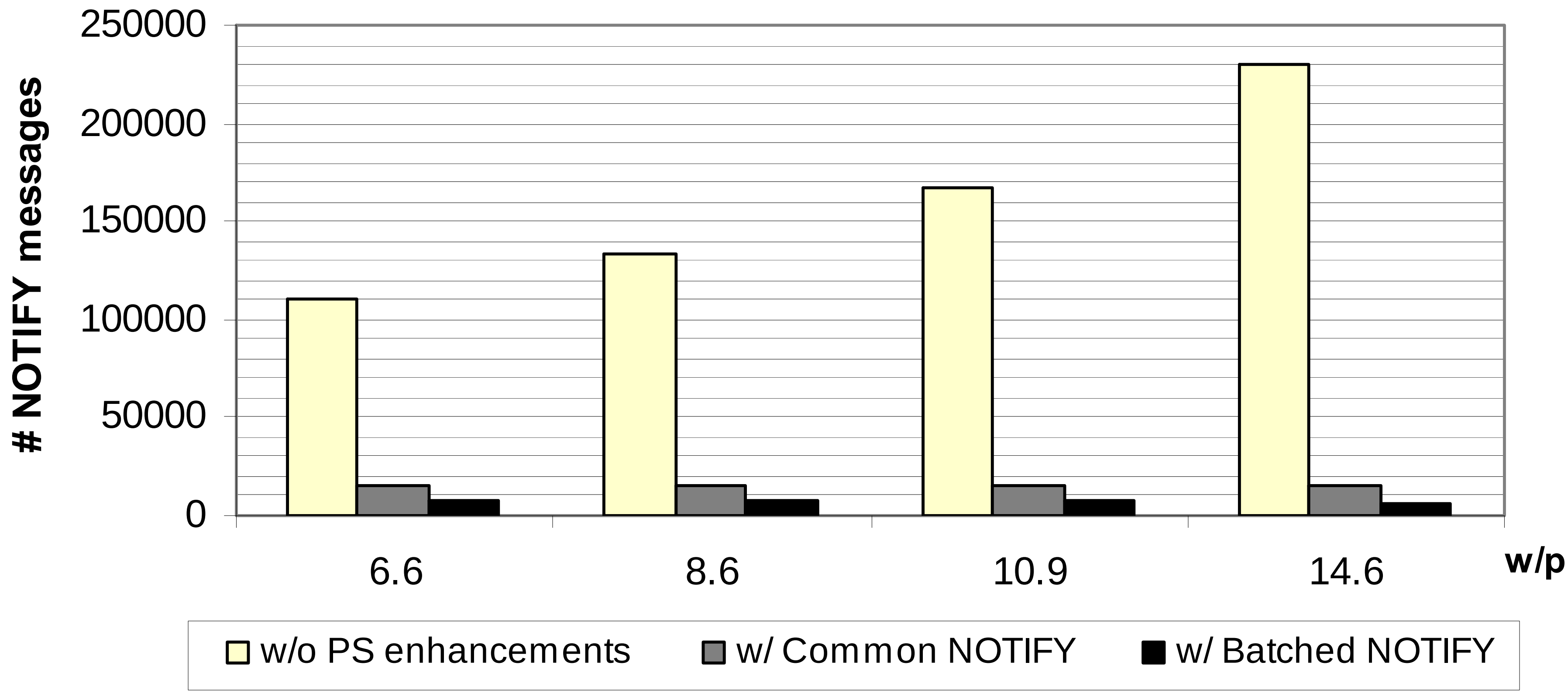


Experimental results:
with IHMAS batched NOTIFY

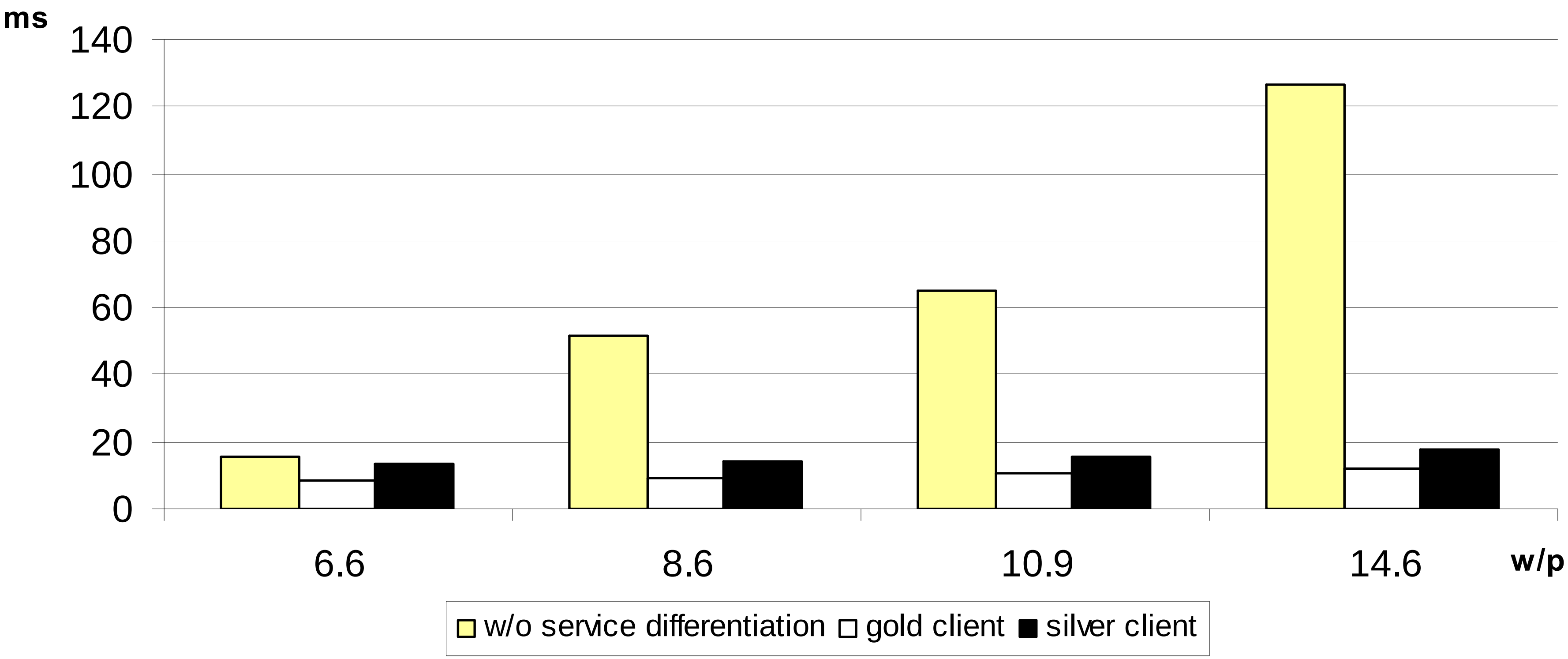




Experimental results:
number inter-domain NOTIFY transmissions



Experimental results:
inter-domain NOTIFY delay



- Conclusions
  - **Good scalability** of the proposed enhancements
  - ***Full standard compliancy,*** necessary for wide acceptance and use

- Ongoing work
  - Extending the support to aggregate also SUBSCRIBE message traffic
  - Intra-domain PS load-balancing solutions are under develpment

IHMAS project web site and contacts

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

- Contacts: Luca Foschini (luca.foschini@unibo.it)

Thanks for your attention!