Practical Experiences with Wireless Integration using Mobile IPv6

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Wired/Wireless Networks Integration

➢ World over, mobile Internet access has shown strong growth due to the worldwide deployment of wireless local-area 802.11b-based WLANs and *pervasive* wide-area GPRS/3G networks.

➢ Multimode devices are becoming increasingly affordable (e.g., GPRS-WLAN cards), and a growing number of mobile devices such as laptops, palmtops and handhelds are equipped to connect to multiple networks.

➢ ***Mobile IPv6 can play a key role in integrating different link-layer technologies, with the promise of enabling transparent mobility through use of a unified network layer.***

➢ In Cambridge Open Mobile Systems (COMS) Project, we are investigating the extent to which Mobile IPv6 can be used to successfully migrate TCP connections during inter-network handoffs. ***Our research is aimed at:***

➢ **Characterizing the handoff *execution* latency components in Mobile IPv6-based vertical handoffs,**

➢ **Identifying transport protocol (TCP) performance problems during vertical handoffs using Mobile IPv6,**

➢ **Explore the extent to which Mobile IPv6 protocol can hide the different characteristics of the disparate underlying link-layer technologies, and,**

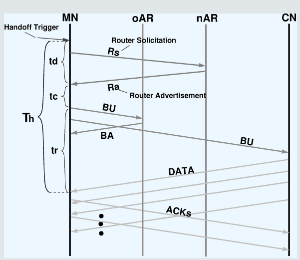
➢ **Demonstrate the efficacy of schemes that improve performance during vertical handoffs.**

Handoff Latency (t_h) in Mobile IPv6

❑ **Detection Time (t_d):**
Depends on the frequency of Router Advertisements (RAs). (also includes Duplicate Address Detection (DAD) time, if any)

❑ **Configuration time (t_c):**
Depends on the computational capability of the mobile device.

❑ **Registration time (t_r):**
Functions of the network latencies and bandwidth.



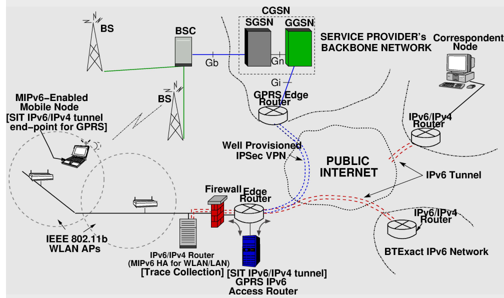
References

[1] R. Chakravorty, P. Vidales, L. Patanapongpibul, K. Subramanian, I. Pratt, J Crowcroft. "On Inter-network Handover Performance using Mobile IPv6", University of Cambridge Computer Laboratory, Technical Report, June 2003 **http://www.cl.cam.ac.uk/coms/publications.htm**

[2] P. Vidales, L. Patanapongpibul, R. Chakravorty. "Ubiquitous Networking in Heterogeneous Environments". in IEEE Mobile Multimedia Communications (MoMuC'2003), Oct. 2003. (to appear).

[3] D.B. Johnson, C.E. Perkins and J. Arkko,"Mobility support in IPv6", (draft-ietf-mobileip-ipv6-24.txt), June 2003. http://www.ietf.org

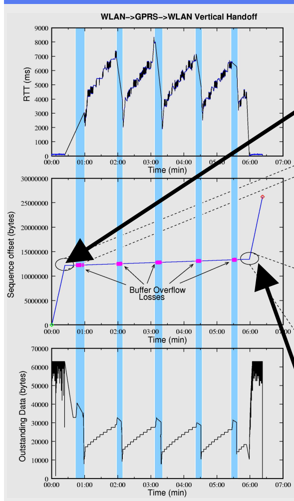
Loosely-coupled WLAN-GPRS-LAN Testbed



Implementation consists of a fully integrated Mobile IPv6 based WLAN-GPRS-LAN testbed.

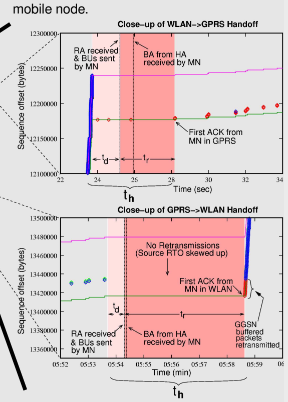
The testbed creates a highly heterogeneous mobile environment.

WLAN—GPRS Handoff Analysis



tcptrace+ plots for WLAN→GPRS→WLAN vertical handoff.

WLAN→GPRS Handoff: TCP session at the source (correspondent node) backs off, and retransmits several times before an ACK is available at the source from mobile node.



GPRS→WLAN Handoff: A long-lived TCP (or large number of flows) leads to excess buffering at the GPRS GGSN, inflating the source RTT, and leading to a grossly inflated TCP RTO.

Summary of Handoff Optimisations

➢ **Exploiting the knowledge of the link-layer conditions can significantly improve vertical handoff performance.**

➢ **Our practical experimentations show that Fast Router Advertisements (RA), RA Caching and Binding Update Simulcast for fast registration can aid the Mobile IPv6 protocol to achieve better handoff performance.**

➢ **A TCP Proxy installed in the GPRS network for smart buffer management benefits handoff performance involving GPRS networks.**

➢ **Exploiting Macro-Diversity using *Soft* handoffs at Layer 3 can *dramatically* improve TCP performance during handoffs.**

Handoff Optimisations

➢ Hard Handoff Optimizations:

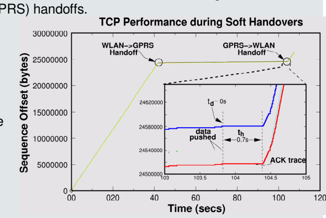
➢ ***Fast Router Advertisement (Fast RAs).*** Fast RAs improve detection times during handoffs. However, by reducing RA interval to very low values (40ms-70ms) as that typically specified by the latest Mobile IPv6 draft [3] leads to substantial overhead in GPRS (up to 25% of total bandwidth), and does not always guarantee significant improvement in mean detection times.

➢ ***Client Based RA Caching.*** RA caching is a technique to eliminate detection time during vertical handoffs. In this scheme, RAs are cached *a priori* by the mobile client, so that when the decision to handoff is taken, the detection time for RA lookup during handoff execution is eliminated, thereby improving handoff performance. We implemented the RA cache as a Linux 2.4 module, and have shown that the benefits of eliminating detection time (t_d~0) during vertical handoffs is significant.

➢ ***Smart GPRS Buffer Management using TCP proxy.*** We have shown that excess buffering due to long (or large number of) TCP connections in the GPRS GGSN node can inflate the source TCP's RTT calculation, and hence, *skew-upwards* the retransmission timeout value (RTO) of that TCP connection. This prevents the source retransmitting during handoff from GPRS→WLAN. Current GPRS networks offer excess buffering (50KB-200KB), and this can be prevented using smart buffer management in GPRS. We implemented a transparent TCP enhancing proxy in user space that uses Linux netfilter and that prevents the source from excessively buffering data. This has shown to give substantial improvements in registration times during handoffs.

➢ ***Client-Assisted Binding Update (BU) Simulcast.*** We observe that when handing off from WLAN→GPRS, the registration process of binding updates (BU) to the correspondent node would entail the high RTT of GPRS link. BU simulcast is a scheme to bi-cast BUs not only from GPRS link, but also from other faster networks (e.g., WLAN/LAN) just before a client decides to handoff. We implemented BU simulcast as an extension to the MIPL Mobile IPv6 source code, and have shown that it can further reduce registration times during upward *vertical* (e.g., WLAN→GPRS) handoffs.

➢ Layer-3 based Soft handoffs:



➢ In hard handovers, the mobile device stops listening on one interface (or that network) and simultaneously *up* (start listening from) the other. As a result, packets that are already in-flight, to the previous network interface, unfortunately, are not read. These packets have to be retransmitted by the source, resulting in loss of performance.

➢ A better technique to handoff across coverage offered by networks in a wireless overlay can exploit the inherent macro-diversity available in order to make handovers soft to help improve performance. We implemented soft handoff scheme as a Linux module (with RA caching), and have found that TCP performance using soft handovers (with RA caching) to improve dramatically with only 0.7s to handoff.

Open Issues for Research

➢ Can soft handoffs applied at Layer 3 be used for high mobility environments? What quantitative benefits can we achieve using a similar approach for real-time flows?

➢ How can we make handoffs smooth for TCP connections (taking account of the link bandwidth-delay product) when handing off from faster/fatter link (WLAN/LAN) to slower/thinner GPRS?

➢ In soft handoffs, can we prevent the source TCP from entering the fast retransmit mode (due to dupACKs generated by the mobile client) during handoff from slow (GPRS) to fast network (WLAN)?