Enhancing Resiliency in Wide-Area Wireless Networks

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In this paper, we first describe the current architecture of wide-area wireless networks. We then identify possible trends in the emerging architecture and present several techniques for improving the resiliency of these wide-area wireless networks.

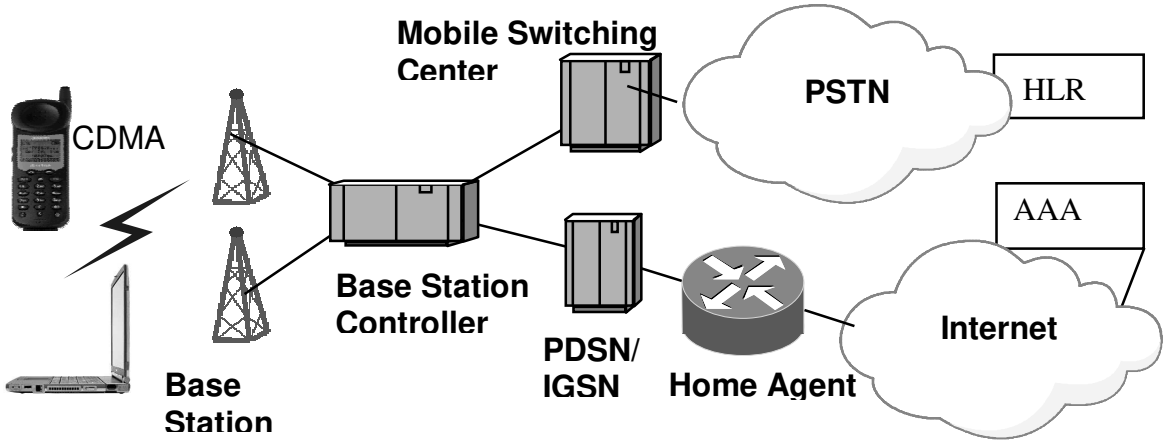

Figure 1: Current Third Generation Cellular Architecture

The third generation (3G) cellular architecture based on the UMTS[1] and CDMA2000[2] standards is shown in Figure 1. Mobile devices connect to base stations using the CDMA-based air interface. Base stations are connected to a base station controller (BSC). BSC performs several network-based wireless functions such as soft-handoff, reverse outer-loop power control etc. At the BSC, the voice and data traffic take separate paths – voice traffic is routed to the Mobile Switching Center (MSC) and into the Public Switched Telephone Network (PSTN) and the data traffic is routed through a packet data service node and a home agent into the Internet. The centralized nature of the architecture makes it susceptible to malicious attacks.

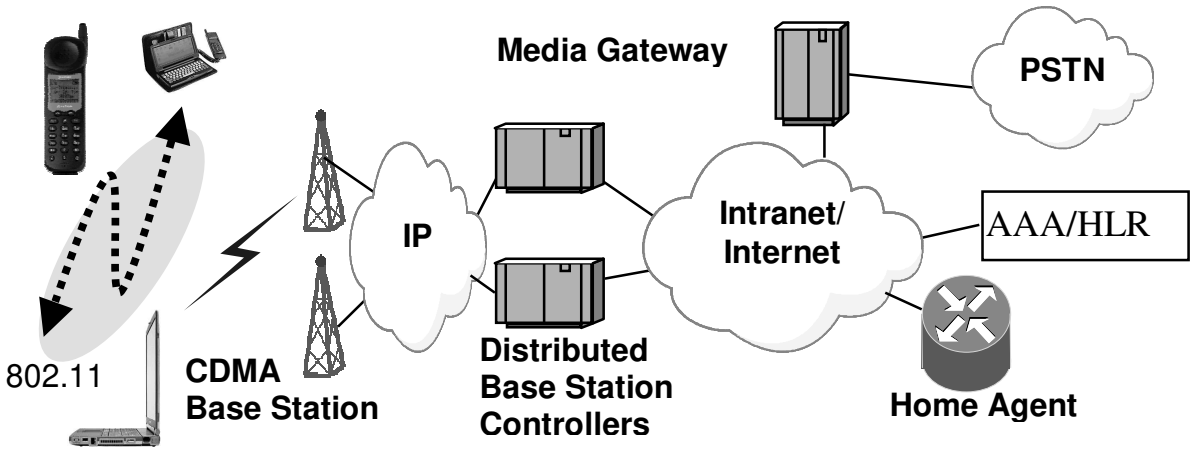

Figure 2: Emerging Third Generation Cellular Architecture

The emerging cellular network architecture is shown in Figure 2. Components that were centralized in Figure 1 (BSC/MSC) are now distributed over IP-based networks, resulting

in flexible network configurations. Also, note that devices are depicted with multiple wireless interfaces such as 802.11 and CDMA.

We now briefly describe several ways of improving the resiliency of wide-area wireless networks in the context of the emerging architecture.

1. Diversity of connectivity in the wireless access network: Note that the emerging cellular architecture consists of base stations that now connect to multiple base station controllers. Obviously, the higher the degree of connectivity, the higher the resilience to failures of links, base stations, and base station controllers. Preliminary results [3] indicate that a small amount of additional connectivity delivers most of the gains in improved network resiliency.
2. Diversity of wireless interfaces available at the mobile device: given that mobile devices will have multiple wireless interfaces in the future, it is clear that allowing the device to use these multiple interfaces simultaneously will improve resilience. For e.g., mobile devices can participate in an autonomous ad hoc network using the 802.11 interface and forward each other's packets to the nearest cellular base station. In [4], we show that this technique can help avoid black holes (e.g. inside buildings) by increasing the cellular coverage and improving performance.
3. Diversity of physical layer techniques to trade-off performance versus resilience: wireless is fundamentally different from wired networks in that connectivity and capacity can be dynamically adjusted in wireless networks by using a number of physical layer techniques. These techniques include power and antenna control (trade-off coverage versus capacity), adaptive coding (trade-off reliability versus performance), and the use of time division duplexing (trade-off uplink versus downlink capacity).
4. Diversity of services: the ability of the network to dynamically adjust the capacity of different services is crucial in dealing with overload situations. For example, during certain disaster situations, the network can switch over to providing only a very low bandwidth service (e.g. reliable text messaging to indicate "all is well") with very low blocking, thereby adapting effectively to overload.

To summarize, incorporating diversity in network design and allowing the network to exploit diversity in a variety of ways is key to enhancing resilience in emerging wide-area wireless networks.

[1] 3G Partnership Project, "Universal Mobile Telecommunication System," Release 99.
[2] TIA/EIA/cdma2000, "Mobile Station – Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular Systems," Washington: TIA, 1999.
[3] T. Bu, M. Chan, and R. Ramjee, "Connectivity, Performance, and Resiliency of IP-based CDMA Radio Access Networks," Bell Labs Technical Report, 2003.
[4] H. Luo et al, "UCAN: A Unified Cellular and Ad-Hoc Network Architecture," in Proceedings of ACM Mobicom 2003.