TRENDING SERIES

Disruptive Technologies

Planning for a mobile and sensor dominated Internet future

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INTRODUCTION

The past decade has seen transformation and disruption in networking due to innovations in smartphone technology, and increased use of wireless sensors. Mobile subscriptions have risen from two billion at the time of the WMPG report to over six billion today. Wireless sensor chips in production could be in the tens of millions by 2015 according to the WMPG (NSF Wireless Mobile Planning Group).

In 2005, a group of industrial and academic researchers gathered to solicit requirements for innovative architectures, and infrastructure, that could better support an expanding wireless and mobile Internet. In this installation of the communications and networking series, we review the WMPG 2005 report, *New Architectures and Disruptive Technologies for the Future Internet: The Wireless, Mobile and Sensor Network Perspective*.

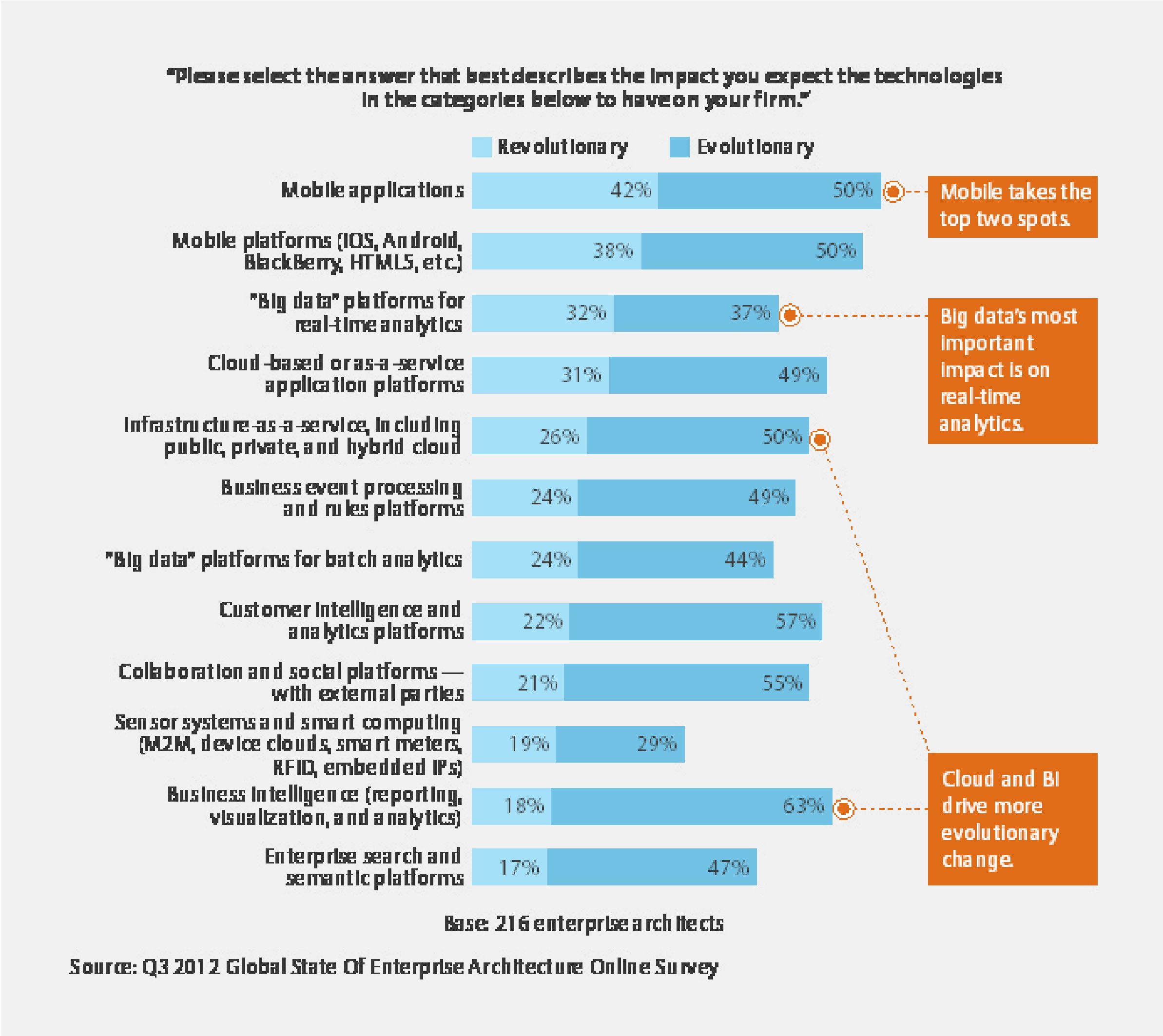
REDEFINING CONNECTIVITY

Mobile connectivity requires unique accomodations, such as continuous connectivity across subnets, that are not fully available in the current TCP/IP implementation. For sensors, while they have limited processing power per unit, they require high levels of QoS (quality-of-service) and data integrity. Layer 2 connectivity creates opportunities for bottlenecks as mobile and sensor devices must connect through gateways to access Internet resources. The current protocols also lack the capabilities to effectively deliver location management, dynamic handoff, QoS and cross-layer transport needed to fully maximize mobile and sensor utility.

Three scenarios were proposed by the WMPG to describe the wireless network, and build a framework for analyzing requirements that research teams could begin to explore. From these three scenarios, the WMPG complied a list of 18 network architecture and protocol design considerations that would require committed NSF funding for the long-term, as well as development of a more robust testing infrastructure to better simulate real-world application of emerging solutions. Below is a summary of the three key scenarios.

Scenario A

The ***mobile computing*** scenario involves a single digital device, such as a celluar phone or tablet computer, connecting to the Internet. The devices are assumed to be highly mobile and faced with intermittent connectivity that spans diverse networks with varying architectures.



The devices must be capable of finding the best connection, while networks need to know what constraints devices are operating under, and throttle content delivery and communications accordingly.

Service models and other requirements for mobile computing include:

- Seamless connectivity;
- Connection hot spots;
- Cached content delivery;
- Location- or context-aware queries;
- Delay tolerant services.

Scenario B

The ***ad-hoc nets***, or constellations of wireless devices, scenario challenges the notion that devices must go to a central location, the Internet, to connect with each other. Instead, cognitive radio technologies would be able to create ad-hoc networks using *physical layer negotiation between nodes*. This could include laptops in the same meeting room, or vehicles on the same stretch of freeway all connecting to share information with each other, and even share the network load needed to download a single file of common interest. Key research considerations for the ad-hoc nets scenario include:

- Opportunistic association;
- Changing network topologies;
- Varying link quality;
- Large-scale network management.

Scenario C

The ***sensor nets*** scenario involves two types of sensor implementations:

- Sensors that collect and aggregate data within a specific geographic area, and
- Closed loop sensor/actuator systems capable of controlling physical world objects in real-time.

Common implementations of sensor nets include home security, ecological and scientific studies, and energy management. Sensor nets are a collection of sensors, typically with limited processing power and memory, that connect to the Internet through one or several repeating wireless gateways. However, there is a need to provide deeper access to the capillary-level components of sensor net devices to access data from a specific segments without overloading the gateways.

NEW ARCHITECTURES

There are three approaches the WMPG proposed in 2005 to deliver a more robust Internet architecture for wired devices as well as mobile and sensor devices.

Wireless-specific IP access network using the current legacy backbone would involve creation of IP+w and IP+s specifications and border routers that would then link to the legacy backbone, or what we know as the current Internet. There is still a risk of bottlenecks at these gateways, and end-to-end services may not meet the requirements for continuous connectivity.

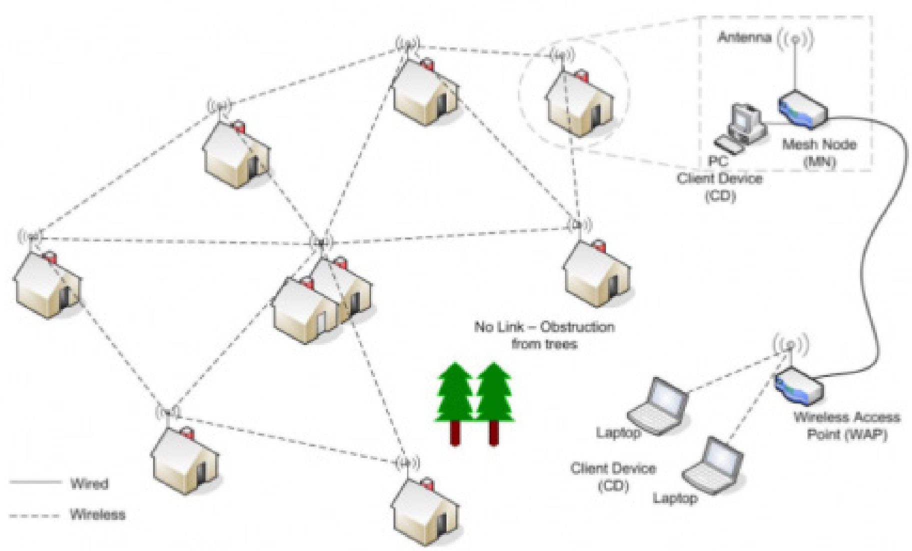


Figure 1: A Community deployed wireless mesh network

Wireless/sensor access network with a global overlay backbone would implement a new IPw protocol to create interconnected global overlay networks that deliver wireless-specific functionality including location services, and attribute-based address resolution. This architecture seems to have received the most attention as it offers lower risk than a full rebuild, as well as the benefits of a protocol that can scale to meet demands of wireless and sensor devices. The challenges with the overlay approach come from an increase in packet overhead and associated latency as more instructions must be included per packet for proper forwarding between overaly networks and the legacy backbone. There is also the risk that fragmented networks will become the norm and reduce benefits derived from a more centralized architecture, like the one that exists today within the current Internet.

Revolutionary wireless/sensor access network and global backbone would essentially rebuild the entire Internet architecture from the ground up to include native functionality for mobile and sensor devices. This is certainly the highest risk approach, however, the costs could be balanced, in part, by having a single end-to-end architecture that is lightweight, centralized and scalable to handle a range of device types and requirements.

LOOKING FORWARD

The work of the WMPG continues through the NSF Future Internet Architecture Program. Created in 2010, universities including Rutgers, CMU and University of Pennsylvania are researching innovative ways for devices to connect to each other without the need for a traditional router-based connection (Talbot, 2013).

One positive aspect of using names instead of IP addresses, as proposed by the NDN (Named Data Networking) project, is that data can be encrypted directly and deliver finer security settings than can be achieved with VPN or firewall implementations (Talbot, 2013). Additionally, new architectures are being developed that allow devices to connect with multiple networks at once (Talbot, 2013). Not only will this ensure the seamless connectivity needed as devices migrate from 4G to WiFi, for example, but they can also boost processing power through network bandwidth aggregation.

Intel estimates there are five billion network-connected devices, and this number is projected to reach 15 billion by 2015 (Talbot, 2013). The need for new architectures is imminent to ensure the future Internet can meet the demands of a growing, and continually disruptive, mobile and sensor device population that is redefining the client-server interaction model.

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