Shared Active Infrastructure and the Virtualization of Wireless Networks

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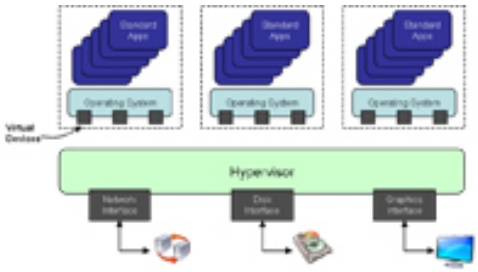

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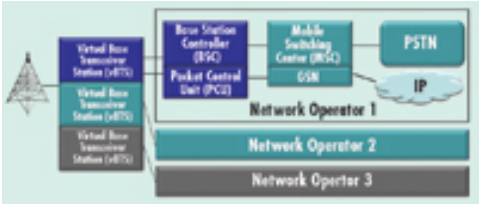
Wireless operators today are finding that the economics of wireless service can no longer justify the ownership and operation of ubiquitous networks. There are parts of the network that must be deployed, due to regulatory build-out requirements or competitive coverage pressure, where the level of service revenue is insufficient to support the operation of those network sites. Increasingly, operators are turning to infrastructure sharing to reduce the cost of network operation at such sites.

Passive infrastructure sharing, where operators share basic site components such as towers, shelters and electrical power supplies, is already commonplace in the wireless industry. In the last few years various operators have investigated shared active infrastructure: the sharing of active electronic components, e.g., base stations and backhaul transmission equipment. Regulators have relaxed rules on ownership of equipment to enable such sharing, recognizing that stringent build-out requirements in rural areas can only be satisfied if operators are able to leverage shared active infrastructure to reduce network costs.

Today's traditional shared deployments have necessitated that participating operators agree upon the same technology, roadmap, and features. The result is significant loss of competitive differentiation among the operators, discouraging operators from embracing the technology and leading to fewer service offerings for customers. A new solution to this challenge is virtualization of the radio access network (RAN), rather than traditional sharing.

Introduction to Virtualization



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Virtualization is not a new technology — it was invented by IBM in the 1970's for use in its System/370 mainframes, and has experienced a massive resurgence in the past decade as a means of logically partitioning a single (hardware) machine into multiple virtual machines. Companies such as VMware have led the way in developing commercial virtualization technology, while various open source efforts, e.g., Xen, have created extremely capable virtualization systems. Both Intel and AMD have extended the basic IA-32 and IA-64 CPU architectures with specific instructions and operating modes to increase the efficiency of virtualized systems.

Figure 1 shows the basic structure of a virtualized system. The key observation to make is that the role of the hypervisor in a virtualized system is analogous to the role of the operating system (OS) in a standard computer system. The hypervisor manages various hardware interfaces, and provides essential services — protection, translation, multiplexing, resource management, etc. — to a number of clients. The essential difference between the hypervisor and the OS is that the OS's clients are application programs, while the hypervisor's clients are virtual machines. Each virtual machine runs its own OS, the guest OS, which in turn manages a set of standard applications.

Another difference is the interface structure: whereas the OS provides application programming interfaces (APIs) to its applications, the hypervisor provides each virtual machine with a set of virtual devices: network interface, disk, graphics adapter, etc. Some hypervisors support the use of a standard, unmodified OS as the guest OS, with virtual devices emulating standard physical devices. Others provide a guest OS environment replicated from the hypervisor's host OS, but incur much lower overhead to do so. The hypervisor may also provide a hypercall API that allows the OS running in a virtual machine to more efficiently invoke certain services of the hypervisor; such a facility is called para-virtualization.

Virtualization is used extensively in enterprise computing environments to support the use of virtual machines for various purposes. Data center hosting providers use virtualization to create a large number of hosted systems on a smaller number of physical machines, while retaining the ability to manage each hosted system as if it was a physical machine, i.e., separate disk quotas, network access and traffic management policies, independent upgrades of OS and applications. Enterprises may use virtualization to separate logical services — web, email, firewall, etc. — without requiring a separate physical server for each one. This enables greater security than running all services within a single OS environment. Finally, virtualization is used by engineers to boot many different guest OS on a single hardware platform for development purposes, e.g., testing of new OS-level software, such as device drivers, or investigation of OS security issues.

Applying Virtualization to Shared Radio Access Networks

Operators who wish to share active infrastructure, particularly the base station subsystem (BSS), do so in order to reduce the cost of deploying and operating certain parts of the network. The challenge they are faced with is the ability to retain independent management and configuration control, and be able to apply software technology upgrades that differentiate them from their competitors.

Traditional hardware radio approaches to shared infrastructure require that operators share a single traditional base station, thus eliminating the ability of each operator to provide independent feature sets or levels of technology. Furthermore, traditional base stations were not designed to be shared, and cannot provide fully independent management and configuration.

A virtualized RAN leverages software radio technology, which implements the complete base station subsystem (BSS) in software, rather than the traditional hardware-based approach. The key element of the BSS that must be shared is the base transceiver subsystem (BTS), the radio system that is located at each cell site and supports radio communications with mobile terminals. A software radio BTS implements all radio functionality, from physical layer through MAC layer and network layer, in software that runs on a standard operating system, e.g., Linux, on commodity off-the-shelf (COTS) processing platforms. This allows a software radio system to take advantage of investment in new technologies and open systems, rather than being limited to a particular radio vendor's own proprietary technologies. In turn, this breaks the vertical integration business model that operators have been forced into in the past and instead creates an ecosystem of horizontally-focused component suppliers that can be integrated into a more flexible and cost-effective solution.

A software radio BTS is much more readily virtualized than a hardware radio, since the BTS is just a software application. It is possible to construct a virtualized base station by using standard virtualization technology to create a virtual machine (VM) per operator, and running an independent BTS application for each operator within that VM. This ensures that each operator has complete control over their BTS, while guaranteeing that one operator's traffic, signaling and configuration data are isolated from other operators.

Figure 2 shows the architecture for a virtualized GSM network supporting three different operators. In this scenario one of the operators deploys the network and acts as an anchor tenant, using excess capacity to provide a managed service to the other two operators in order to reduce the cost of operating the network. Although superficially similar to a traditional roaming network arrangement, the virtualized network provides each operator with full independent control of their own virtual BTS (vBTS), and connectivity to their own BSC and core network.

An alternative model for use of virtualized RAN technology is the neutral host model. In this case the sites are owned and operated by a company that is not itself a mobile network operator, thus eliminating any conflict of interest concerns that arise when the anchor tenant is a competitor of one of the other site operators. Existing tower companies are natural candidates for neutral host management, and

this approach fits in very well with the current trend towards provision of managed network services on a charging by traffic basis.

Conclusion

Shared active infrastructure is an essential technology in the mobile network operator's ongoing efforts to reduce the cost of providing service, particularly in sparsely populated areas where revenues are too low to make service in those areas economically attractive. Vanu, Inc.'s MultiRAN product is a solution that combines software radio solutions with virtualization technology to provide mobile network operators the cost savings of shared active infrastructure while allowing them to retain independent management control and technology evolution.

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