WIRELESS NETWORK VIRTUALIZATION

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ABSTRACT

Virtualization refers to creating a set of logical architectures using a given set of physical entities, but in a way that is transparent to the user. Virtualization of wireless networks involves both infrastructure sharing and spectrum sharing. In addition, there are many different topologies for wireless networks (infrastructure and ad hoc and within ad hoc, single and multi-hop), different spectrum bands from several hundreds of MHz to several GHz, unlicensed versus licensed spectrum bands, different geographic coverage (wide, metro, local and personal area) and finally different mobility requirements. Know network virtualization, learn the limitations of virtualization, and learn the components. The provision of virtualization in wireless networks is a promising concept that has the potential to alleviate spectrum congestion and open up new services. In this paper, we have discussed three paradigms for virtualizing wireless networks: (1) universal, (2) cross-infrastructure, and (3) limited intra-infrastructure. Paradigms differ in the degree of virtualization and infrastructure sharing. Network virtualization, regardless of whether it is a wired or wireless environment, can be thought of as partitioning the entire system. The network can be thought of as composed of Infrastructure Providers or InPs who build and manage only the infrastructure (eg base stations, MMEs, S-Gateways, APs, spectrum, etc.) and Service Providers or SPs who actually provide various services to subscribers.

Keywords: Virtualization, Technical Approach, Signaling, Isolation.

1. Introduction

Virtualization of wireless networks involves both infrastructure sharing and spectrum sharing. In addition, there are many different topologies for wireless networks (infrastructure and ad hoc and within ad hoc, single and multi-hop), different spectrum bands ranging from several hundred MHz to several GHz, unlicensed versus licensed spectrum bands, different geographical coverage (wide, metro, local and personal area) and finally , different mobility requirements.

2. Literary review

D.Tipper & P.Krishnamurthy: Virtualization of computing systems is characterized by three characteristics: isolation, customization, and resource efficiency.

3. Objectives

1- Know network virtualization
2- To find out the limitations of virtualization
3- To find out the components

4. Scope

Virtualization of wireless networks. Technological approaches.

5. Research methodology

In this research paper, I used second-hand information from many academic papers such as: ACM Computer Communications Review, Journal of Communications, wireless networks using coordinated dynamic spectrum and others.

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6. Data analysis and discussion

Virtualization refers to creating a set of logical architectures using a given set of physical entities, but in a way that is transparent to the user.

For example, a physical server composed of processors, memory, and network interface cards, and storage can be used to create a set of "virtual servers that all use physical hardware, but users see these virtual servers as separate entities in their own right." The task is to allocate physical entities to virtual entities in a certain way.

Which maximizes the use of physical entities while providing the user with the desired performance. Ideally, such allocation should be dynamic depending on user needs. Furthermore, the allocation process itself should not be cumbersome or resource intensive. The reasons for virtualization are increased hardware efficiency, easier migration to newer products or technologies while supporting older products, and overall reduced equipment and management costs. Virtualization of end systems such as servers and cloud computing systems is now widespread and common. Note that the concept of computer system virtualization is actually an old idea [1] that originated at IBM during the 1960s, but the concept did not gain traction until economic considerations became a dominant factor. Currently, the virtualization of computing systems is characterized by three characteristics: isolation, customization, and resource efficiency. That is, isolation of users, adaptation of services and increased load on systems. Virtualization is well established in wired networks with virtual private networks (VPNs) in service provider networks at different layers (eg optical wavelength, MPLS, etc.) common in WANs and MANs and VLANs. Virtual local area networks (VLANs) are also widely used in wired enterprise networks. In general, virtualization is achieved by logically dividing a physical network into virtual networks that share physical routers/switches/cross-connects, physical links, and bandwidth on each link. Physical resource utilization must be carefully managed to maintain the quality of service (QoS) and security needs of the users of each virtual network. In the case of WAN and MAN networks, the process of setting up/tear down and managing virtual networks is usually strictly controlled by the service providers. This has led to recent efforts to virtual overlay/over-the-top networks that can span multiple service providers and research efforts to provide more general virtualization that can be managed/configured by users in next-generation network architectures. The motivation for virtualizing wireless networks stems from the perceived benefits of wired networking. First, it becomes a natural extension of cable network/end system virtualization and can potentially enable segregation of traffic (eg in terms of QoS, security) and provide a mechanism to support the popular idea of bring your own device (BYOD) to organizations. . Second, spectrum is a scarce resource and spectrum virtualization has the potential to ensure better utilization, making it more efficient for operators. Third, it enables the separation of operators from the costs of infrastructure ownership (capital and operating expenses) and also separates service providers from operators. In such cases, users simply subscribe to services or applications. Operators only provide an access service. In other words, it can even separate users from operators! Last but not least, it will probably support the creation of new services. When virtualization is applied to wireless networks, things get complicated quickly and there are big differences from virtualized wired networks. Virtualization of wireless networks involves both infrastructure sharing and spectrum sharing. In addition, there are many different topologies for wireless networks (infrastructure and ad hoc and within ad hoc, single and multi-hop), different spectrum bands ranging from several hundred MHz to several GHz, unlicensed versus licensed spectrum bands, different geographic coverage (wide, metro, local and personal area) and finally different mobility requirements. When wireless networks are deployed, interference that is caused within an administrative unit (e.g Provider network) and across administrative units becomes important. Physical entities in wireless networks can be as diverse as a complex mobility management entity in 4G cellular networks to low-cost access points in Wi-Fi networks. In addition, the air interface and bandwidth segments used by different technologies can be very different. Protocols in the air (access) and in the backbone (core) networks can vary greatly between technologies. Unlike wired networks, users and services can also be mobile in wireless networks. Finally, it is worth noting that governments heavily regulate the underlying source of spectrum and how it is used. There is still no unified vision of what wireless network virtualization means and how it can be achieved. Recently, there have been attempts to single out areas where virtualization of wireless networks appears to be possible, albeit in a limited way. This work was motivated by two different activities, namely: (a) dynamic spectrum access work and (b) virtualization work within a specific technology (e.g. LTE, WiMAX, etc.) for a specific scenario (e.g. infrastructure network, mesh network etc.). In this article, we present our perspective on wireless network virtualization. We provide some background on recent work in this area in Section II. In Section III, we describe three wireless network virtualization paradigms. Part IV addresses the challenges and barriers to implementing virtualization in wireless networks. Finally, Section V concludes the paper.

State of the Art

Recently, work has been done that has started the discussion on virtualization of wireless networks. We can classify the literature according to whether the origin is rooted in (a) dynamic access to spectrum for cellular networks dominated by mobile virtual network operators (MVNOs), or (b) based on the technologies considered (e.g., cellular vs. Wi- Fi in infrastructure or ad hoc mode). In this section, we will briefly discuss some of these works (see **A. DSA and MVNO Approaches**

Work coming from DSA Dynamic Spectrum Access (DSA) overcomes the barrier between traditional regulated frequency bands. It creates an open environment for any entities to use the available spectrum. Much of the research effort related to DSA is in the field of cognitive radio networks. Cognitive radio based networks use a decentralized paradigm I theory in the literature [4]-[6]. In this model, there are no barriers or obstacles to the use of spectrum across the entire bandwidth. The spectrum fund is exhausted based on user demand. In other words, the wireless network evolves in a virtual environment with the presence of the DFB. Spectra users run their operations without knowing the underlying architecture. However, wireless network virtualization, as described later in this article, is an even broader concept than a DFB system.

(2) Mobile virtual network operator access A mobile virtual network operator (MVNO) is a special network operator that leases radio access from a mobile operator (MNO) host. MVNOs can be considered a special implementation of wireless virtualization. The strict definition of MVNO varies from country to country [7]. Typically, an MVNO leases spectrum from one or more PMSs and connects its own subscribers to its own exchange. Alternatively, the network operated by the MVNO may also be connected to MNO networks that have agreements with the MVNO. The key difference between MVNOs and MNOs is that MVNOs do not own any radio access networks and spectrum. In some countries, regulators may require mobile network operators to open up networks to mobile network operators to enhance competition. On the other hand, mobile network operators may also enter into voluntary cooperative agreements with mobile network operators to obtain certain benefits. For example, MVNOs can address or test new market segments, use free network capacity and introduce new services that can complement existing services provided by the mobile network operator [8]. While the MVNO concept may bring much-needed service differentiation to the cellular network, it is still not a full virtualization model for the overall wireless network. In the long term, MVNOs mostly rent a fixed amount of resources (e.g. transmitted bits) from mobile network operators in a static manner. Currently, radio resources in the access network are not shared dynamically among multiple MVNOs or among MNOs in fine granularity. This approach has been proposed for LTE, as discussed in the next section.

Technology-oriented approaches

(1) Based on LTE: The use of LTE for virtualization has been recently explored in the literature. The idea is similar to virtualizing routers/switches in wired networks. The work in [9]-[11] proposed an entity called "Hypervisor" on top of the physical layer in base stations in LTE (called e-NodeB's or eNB's). The hypervisor virtualizes an eNB into a series of virtual eNBs (each managed by a virtual operator) . The hypervisor also allocates air interface resources (called physical resource blocks or PRBs in LTE) among multiple virtual eNBs. The virtual operators share the LTE spectrum based on QoS criteria and provide feedback to the hypervisor in each time unit. The hypervisor collects information from individual eNB virtual stacks, such as user channel conditions, traffic load, priorities, QoS requirements, and contract-related information of each virtual operator [9]. The hypervisor can schedule air interface resources between multiple virtual networks in each time unit. Various configuration methods can be used to complete the scheduling [9]-[11].When the spectrum allocation budget closely replicates the traffic load, multiplexing gains are reported based on simulations of such virtual networks.

(2) WLAN-based: Virtualization of WLAN access points was considered in [12]. Rather than spectrum pooling, this work considers the allocation of limited spectrum resources in an optimal and fair manner. To this end, the authors manipulate in each virtual WLAN a contention window in IEEE 802.11

CSMA/CA protocol based on access control medium. A "Split AP" architecture was also proposed in [13].

Airtime fairness for a group of WLAN users. One physical access point can emulate multiple virtual access points associated with corresponding users. Designing a virtual appliance typically requires three basic principles – abstraction, programmability, and isolation. Abstraction makes it possible to divide one physical structure into multiple virtual ones. Programmability controls virtual access points. Isolation ensures that system performance for each virtual network is not affected by other virtual networks. The complexity of incorporating a virtual network into a physical wireless mesh network is studied in [14].

(3) Based on WiMAX: The ―virtual base station‖ design was designed using the three basic principles of virtualization mentioned above (resource efficiency, isolation, and customization). Add-ons and modifications needed for WiMAX base station virtualization are described in [15]. A virtualized base station performs frame switching at the MAC layer. Meanwhile, the isolation mechanism greatly improves the aggregate throughput for different classes of users. Another general framework for virtualizing WiMAX networks comes with an optimal segment scheduler aimed at adapting isolation and efficient resource utilization [16]. Concave utility functions are defined and maximized using a simple weighted solution. Although isolation and adaptation can be achieved using a weighted fairness algorithm on a long-term basis, it is difficult to ensure an efficient transfer rate for each user in each time unit. Furthermore, operations over multi-cell and wider geographical areas have not yet been studied.

(4) Based on a mobile platform: The trend of massive smart phone use suggests that the primary platform for mobile users in the future will be small devices whose computing capabilities are limited by batteries and processors.

The migration of computing from small mobile devices such as tablets to desktops or laptops that have more resources and processing capabilities is also discussed as a topic of virtualization. Computational migration becomes important for the development and use of some complex mobile applications. This type of virtualization requires hardware support, such as supporting the existence of operating systems and software virtualization. The work in [17] presented a usage model that offloads computations between virtual machines using a fast local wireless network. While not necessarily wireless network virtualization, we mention it here because it relates to end devices, but we won't go into it further.

(5) Based on the choice of approach: The above technology-oriented work related to virtualization considers either models for networks or specific platforms. Network virtualization usually takes place at the MAC layer on a single network component. Mobile computing migration can be considered an application layer transition, although it has some hardware requirements. Recently, a new term "virtual cell" was proposed in [18].

III. **The Wireless Network Virtualization Paradigm**

In general, network virtualization, regardless of whether it is a wired or wireless environment, can be thought of as partitioning the entire system. The network can be viewed as composed of infrastructure providers or InPs that build and manage only infrastructure (eg base stations, MMEs, S-Gateways, APs, spectrum, etc.) and service providers or SPs that actually provide various services to subscribers. Resources that belong to one or more InPs are virtualized and partitioned. The SP requires at least one segment of resources from the InP and provides end-to-end services to end users without knowing the underlying physical architecture of the InP. By dividing resources into slices, each slice creates the illusion of being a complete system in itself. This ―slice‖ system consists of its own (virtualized) core network and (virtualized) access network corresponding to the wired segment and the wireless segment. In recent research work, various analytical and experimental models have been proposed to visualize wireless virtualization and evaluate virtual architectures [5], [6], [9]-[11], [19], [20]. On the one hand, work that focuses on market profit views the virtual wireless network simply as a pool of spectrum with hierarchical DFB management, as described earlier. In such cases, two types of interactions are studied – between users and service providers or between service providers and service providers. Such interactions are usually modeled as stochastic games. The existence of a Nash equilibrium [5] can lead to an optimal spectrum price. On the other hand, research that focuses on the implementation of wireless virtualization chooses a specific platform such as LTE or Wi-Fi. These works consider case studies and run simulations to evaluate the technical benefits of virtualization. Compared to the work that deals with spectrum pools, the related work on technical implementation is limited. Several works also focus on the virtualization of a single BS to meet the requirements of multiple MVNOs. Some optimization techniques, such as weighted segment allocation, are integrated into the physical BS to create opportunities for MVNOs. MVNOs can then adapts its own virtual BS [20]. However, MVNOs will need to be able to virtualize the backbone network and its components (signaling, mobility management, security functions, localization, etc.). In short, even the understanding of what wireless virtualization means is not clear in the literature. Inspired by different degrees of virtualization, this paper proposes three paradigms for wireless network virtualization using the idea of InP and SP, namely: (1) universal, (2) inter-infrastructure, and (3) and limited intra-infrastructure. As shown in Fig. 2, the three paradigms from (3) limited intra-infrastructure to (1) universal have progressively more virtualization.

A. Universal Virtualization: The big vision of wireless network virtualization is to make no assumptions about InP or SP. This view of wireless network virtualization looks at the entire radio access path as an "unbundled cloud" where virtualization is ubiquitous. The cloud consists of heterogeneous base stations (macrocells, picocells and fem-cells, relays and other types of access points wired backbone networks) that are transparent to the user [6]. It is the responsibility of the specific service provider to select a package of network components, links and spectrum, and the provider configures them as desired. Ideally, this could happen dynamically in an on-demand manner. For example, to support a particular application, such as one that involves extremely low-power transmissions at low speeds with not very strict delay constraints, network components can be used fem-to-cells using a small slice of the spectrum or even sensor relays that use multiple hops to goals. This "cloud" virtualization has complicated management, control, and economic issues that have not been considered in the literature. For example, how many and what type Management options are given to SPs on the InP system, how SP isolation can be enforced, and how mandated/regulated services such as E-911 localization can be provided are open issues.

B. Virtualization Across Infrastructure In this paradigm, we assume that wireless virtualization is possible across InPs (inter-InPs) and within InPs. This allows all InPs in a geographic area to share their network resources between SSPs. A simplified example is shown in Fig. 3. In this example, base stations (BS) 1 and 2 belong to InP 1, while BS 3 and 4 belong to InP 2. The two SPs in the system are SP A and SP B. And centralized must be established management to ensure cooperation and isolation between InP (an entity appointed for this purpose

"Resource Manager" is added above InP). Note that the InP may have bandwidth segments in different frequency bands that support multiple radio access technologies (RATs) such as GSM, UMTS, and LTE. Inter-InP virtualization enables spectrum sharing between different InPs, SPs and different RATs. InPs that cover the same area (for example BS 1 and 3 in Fig. 3) provide their physical resources to the SP. SPs are allocated specific resources based on their requirements, each specific time unit. Not only radio resources are shared between different SPs, but also nodes and links that connect the access network to the core network. These backhaul nodes and links should be shared in a virtualized manner. There are no clear boundaries between multiple network infrastructures belonging to different InPs. It is as if all sources are in the same pool for SP utilization (eg in Fig. 3 the frequencies f1A, f1B, f3A, f3B are in the same pool). Service providers can choose the source with the best quality or the lowest price. However, inter-InP wireless virtualization has strict coverage/interference requirements. InP coverage should either completely overlap or there must be a way to determine which BS from which InP covers which part of the geographical area. Otherwise it may be there―service holes‖ when users enter an area not covered by the set of InPs used by SPs. Due to the limited wireless coverage of each cell, this virtualization design may be more suitable for certain areas (eg urban) that have highly overlapping multiple cells from several InPs. Several factors need to be considered when designing an appropriate virtualization strategy across infrastructures, such as the entire network architecture, QoS promised by each SP, management of mobility and spatio-temporal variations of traffic, cross-InP signaling and location tracking. . Thus, fully centralized management may be preferable for wireless virtualization across infrastructures. A well-designed centralized strategy will be more likely to deliver significant improvements in network utilization, reliability and quality of service. However, a bad strategy may encroach on the reserved resources of a service provider, and such a provider may not be able to provide a level of QoS to its users, especially highly mobile users and users at the edge of coverage due to poor channel quality or excessive interference.

C. Limited virtualization within the infrastructure Limited wireless virtualization, in our opinion, only considers virtualization within a single InP, which may have spectrum that is used by different RATs. Spectrum sharing takes place between SPs and between RATs. For a given cell, we can imagine one InP that can manage its resources and decide on their allocation to different SPs. The gains from multiplexing are likely to be lower than those possible with a cross-infrastructure strategy because there may be InPs with demand from service providers that is greater than they can satisfy, while other InPs have resources that are not fully utilized. Limited virtualization can be described with an example in Fig.4. In cell 1 of cell system two SPs A and B rent a certain amount of resources from BS 2 in each time slot. BS 2 is virtualized and is in charge of the f2A and f2B spectrum allocated to the SP. This is similar to some work done in BS hardware virtualization (e.g. [15]) described earlier. Each service provider can be viewed as a virtual operator (VO) with time-varying resources based on factors such as its own requirements, the amount of money it is willing to pay for resources, fairness, and other InP policies. In a sense, this is similar to a single-level DFB structure, where we can think of the InP as a DFB that allocates spectrum to nodes in its area and the SPs as those nodes. In addition to scheduling, this paradigm could also work in another way like the decentralized spectrum sharing behavior that now exists in cellular networks in the last few years, namely layered networks. In some literature, this idea corresponds to overlay-underlay networks. In this architecture, the system takes advantage of differences in coverage and radio access conditions between InPs. Small cells nested within large cells can universally reuse their frequency bands. However, the overlay network formed by Pico/Femto cells must be self-organizing by evaluating SINR between layers. In wireless virtualization, all cells are coordinated under a central control.

Discussion Questions There are several issues that arise regardless of the wireless network virtualization paradigm adopted (although the specifics will likely vary in degree of complexity). As an extension of wired network virtualization, the technical challenges regarding the implementation, operation, and management of wireless network virtualization need to be better explored [21]. Most existing works focus on spectrum allocation models, for example, some theories such as auction game winner determination problems are used to model spectrum allocation [5], [6]. A little Experiments were performed on hardware test plants [22], [23]. However, important issues such as interface, signaling, mobility management, isolation, customization and enforcement have not received much attention. In this subsection, these issues are discussed as challenges mapped from the wireframe perspective presented in [21].

(1) Interface: Wired virtualization requires virtual networks to express their needs using virtual nodes and virtual links in a standard specification language [21]. In wireless virtualization, SPs require radio resources (bandwidth, power, interference) from one or more InPs. Since service providers may use different RATs on the same InP, a well-defined common interface is necessary for the InPs to understand the radio resources required by the service providers. Moreover, with more InPs, the need for a standard language to express the explicit sharing of information between them arises. Communication between service providers and between end users and service providers also needs to be standardized.

(2) Signaling and bootstrapping: An SP must have a network connection to one or more InPs to make its requests before creating a virtual network. Signaling must be handled correctly (in terms of delay and reliability) for the InPs or hypervisor to allow configuration

(3) Resource Allocation: A well-known problem in wired virtual network is how to embed a virtual network into a physical network (i.e., which nodes, links, and resources should be selected) [21] and is also important in wireless virtualization [14]. Inserting virtual networks with resource or demand constraints can be reduced to an NP-hard optimization problem. In market-oriented analyses, the problem usually focuses on maximizing the revenue of each InP with limited QoS requirements of the finite spectrum and SP [6]. In cross-infrastructure virtualization, constraints such as limited radio resources, SPs QoS requirements, and different InPs policies need to be included in the problem.

4) Resource discovery: In order to allocate resources to SPs, InPs or hypervisors should be aware of the available radio resources of the wireless network. Coordination between InPs should be done before each InP allocates its SPA resources. InPs may need to reserve some resources for themselves, in which case InPs must decide what radio resources to keep and how much they are willing to share. Resource discovery and allocation presents another important network management issue—the transmission time interval (TTI), or the unit of time between each resource discovery and allocation. Obviously, the cost will be staggering if the period is short. However, low update frequency (eg monthly SLAs) can drag the network back to a traditional static architecture.

(5) Isolation: The performance of wireless networks is much more sensitive to interference than wired networks, so isolation between different users or service providers is essential. In [20], a Segment Isolation Module (SIE) is used to limit segment traffic regardless of the clients and classes of service agreed upon earlier. Another way to deal with isolation is to incorporate it into the spectrum allocation problem. This can be considered as a limitation in terms of the specific distance between paired spectral channels [6] for frequency duplex systems.

(6) Mobility management: Mobile users should be able to seamlessly switch to a contracted service provider. An even better scenario is that users can access whichever SP offers the best QoS or lowest cost in a given location. Wireless virtualization facilitates this mobility management by sharing spectrum/infrastructure and protocols between service providers and service providers to ensure that users have access to the most appropriate service provider.

(7) System operation: Wireless virtualization may require all InPs to share their physical resources. If the coverage of several InPs overlaps or demand is low, it may be possible to save costs by carefully shutting down some BSs and sharing the resources of other BSs. BSs may need additional hardware and software enablers to accommodate the expanded spectrum/RAT capabilities. Such system operations must be consistent with resource discovery, allocation, isolation, etc. A. Wireless Virtualization Limitations

(1) Limited resources: Unlike cloud computing, the economies of scale that make virtualization a viable model may not always be applicable to the wireless domain. Coverage in rural areas is often a problem. A smaller number of BSs with limited capabilities in rural areas may not leave enough resources to share, so virtualization becomes meaningless. Although the amount of reserve resources may be greater than in urban areas, the distribution is geographically uneven. Furthermore, spectrum is a regulated resource that cannot be easily added to a specific geographic location, unlike cloud computing where additional computing resources can be added quickly.

(2) End devices: Wireless virtualization may require adaptation of end devices to allow them to access a wider range of carrier frequencies. Flexible spectrum sharing requires enablers such as frequency agility wideband radios and direct conversion architectures. The end device must be equipped with hardware to allow it to access the entire frequency band. Software should also be available to calculate spectrum sharing algorithms.

Non-Technical Challenges Technically, the potential gains from multiplexing and better spectrum utilization appear to be good reasons for wireless network virtualization. However, virtualization of wireless networks is unlikely to happen in practice and may suffer the same fate as many other promising but failed technologies without good economic justification and a favorable regulatory environment. One of the few papers that illustrates a (limited) virtualized wireless network use case is the work in [24], which uses enterprise cloud access from mobile devices as a motivating example. From a regulatory perspective, spectrum ownership, physical infrastructure and service provision will probably need to be separated. Legacy service providers are unlikely to be willing to readily share their resources unless strong economic and regulatory reasons arise. In addition, many techno-economic issues need to be resolved, such as how the spectrum contributions from different InPs in the common pool should be evaluated and scored, as spectrum bands are not completely substitutable [25]. In addition, forany useful spectrum to be virtualized, one-way broadcast communication will also need to be considered and support for legacy devices will need to be carefully explored.

Conclusion

The provision of virtualization in wireless networks is a promising concept that has the potential to alleviate spectrum congestion and open up new services. In this article, we discussed three paradigms for virtualizing wireless networks: (1) universal, (2) cross-infrastructure, and (3) limited intra-infrastructure. Paradigms differ in the degree of virtualization and infrastructure sharing. Each paradigm includes technical and non-technical hurdles to overcome before wireless virtualization becomes a widespread technology. To make wireless network virtualization a reality, these challenges require careful design and evaluation.

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