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Efficient Exploitation of All Wireless Networks around Us – The Right Approach

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ABSTRACT: The ever growing rise in popularity of smart mobile devices and utility of wireless applications has resulted in a dramatic growth in wireless data traffic. There is a spurt in demand for mobile internet access and real time wireless applications due to the availability of wireless networks around us like Wireless Local Area Networks (WLAN), Wireless Fidelity (Wi-Fi) hotspots, Worldwide Interoperability for Microwave Access (WIMAX) and 3G/4G/5G cellular mobile networks, in addition to the wired networks. Most of the mobile devices also have bluetooth and ad hoc networking capability. Central and state governments have also initiated provision of free Wi-Fi services at public places like Air Ports, Railway Stations, Parks, etc. Thus we have heterogeneous networks (HetNets) around us, on the move, wherever we go. In addition, integration of any new wireless network with the existing wired/legacy system is also essential. For example, communication between wired devices and mobile devices is also prevalent to a good proportion, in all parts of the world. Thus it becomes imperative that we are able to get the maximum benefits out of the heterogeneous networks around us, when we are on the move. This paper reviews the design and implementation of efficient optimization algorithms and mechanisms for extracting maximum utilization of the heterogeneous networks around us.

KEYWORDS: wireless communication; heterogeneous network; optimization; bandwidth; quality of service

I. INTRODUCTION

The wireless communication revolution is bringing fundamental changes to data networking, telecommunication, and is making integrated networks a reality. By freeing the user from the cord, personal communications networks, wireless LAN's, mobile radio networks and cellular systems, harbor the promise of fully distributed mobile computing and communications, anytime, anywhere. Focusing on the networking and user aspects of the field, Wireless Networks provides a global forum for archival value contributions documenting these fast growing areas of interest. Wireless networking is an essential productivity tool for today's mobile workforce. With wireless networking, all employees can stay connected to their company's information resources virtually anytime, anywhere. Every minute counts in a small company and wireless networks are a powerful tool for boosting productivity and encouraging information sharing. With untethered access to documents, emails, applications and other network resources, employees can roam where they need to and have constant access to the tools required to do their jobs.Some IT organizations encourage their employees to adapt Bring Your Own Device (BYOD) strategy for improving their productivity.

In the present scenario, we have a capricious blend of co-existing radio access technologies. Thus we have ample options of networks, access techniques, radio interfaces and overlapping coverage. The heterogeneous networks around us use different network architectures and protocols.

II. RELATED WORK

A. *Bluetooth*

Bluetooth is the established short-range wireless communications technology for creating a Personal Area Network (PAN). Bluetooth specification 2.0 implemented an enhanced data rate (EDR) of up to 3 Mbit/s. Bluetooth also

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follows the trend toward lower power consumption. The Bluetooth low energy (LE) technology, "Bluetooth Smart" has been adopted in Bluetooth specification 4.0 to achieve an ultra-low power solution that mainly addresses the Internet of Things (IoT).

B. *Booming Data Traffic*

The article "Wi-Fi deployment gains momentum amid shortage of mobile-phone bandwidth" which appeared in The Hindu [1], issue dated February 1, 2016 states that growing number of people with advanced smart phones and wanting to stay connected has facilitated rapid adoption of Wi-Fi deployment. According to the Internet and Mobile Association of India (IAMAI), India has booming data traffic: the number of mobile Internet users in India is expected to be 314 million by next year, up from 173 million in December 2014.

C. *Free Public Wi-Fi Services*

A free high-speed public Wi-Fi service was unveiled at Mumbai Central Station by RailTel [1], the telecom arm of Indian Railways in partnership with Google in January 2016. RailTel plans to roll out this project to 100 stations across the country in2016. In Karnataka BSNL has set up a high speed Wi-Fi service at 20 popular spots in January 2016. In November 2015, Facebook said it was partnering with BSNL to create 100 Wi-Fi hotspots in rural India.

D. *Wi-Fi – An Enabling Medium*

According to theexpert of a wireless network equipment manufacturing company, already Wi-Fi is the indoor data technology. LTE and Wi-Fi will converge [1].Many operators, especially in the U.S., are adopting Wi-Fi calling. According to another expert, while 3G and 4G have not been able to handle mass volume of bandwidth, Wi-Fi provides it. India has 5.5 million 4G-capable devices but only about 85,000 subscribers are active LTE users.

E. *Interference and Security*

One of the Challenges networks face is interference, caused by radio frequency signals from devices nearby. A way to avoid interference is the usage of adaptive antenna technology that fights interference and maximizes signal coverage throughput and network capacity. It can steer every packet to a path that has the least interference in real time.

Security is another issue. Cloudpath[1] is a more secure method, as it uses encryption and not password-based. When a device signs on, one-time authentication is done. After that, the network will push a certificate on to the device. It can be managed by the Wi-Fi Service Provider. They can revoke it or specify the duration of the contract. Cisco, HP, Aruba, Ericsson, Motorola, Ruckus Wireless, etc. have similar security solutions.

F. *Future Networks*

We also have voice over LTE (VoLTE), a way to route voice traffic over the 4G LTE networks carriers use to transmit data. VoLTE has the ability to use voice and data at the same time, provide better quality voice calls and more network efficiency.There are also many revolutionary techniques with promising applications like Internet of Things (IoT), Cloud Radio Access Network (C-RAN), mobile cloud computing and Long Term Evolution (LTE) for Vehicle-to-Everything (V2X) services. Internet applications like E-Commerce, M-Commerce, net banking, social networking, E-Governance, online courses, online purchase, etc. has come to stay and is prevalent today in most parts of the world. Different categories of people use smart mobile devices of their choice based on their need (profession, education, entertainment, etc.) and requirement (processing capability, storage, bandwidth, etc.).

Modern mobile phones can support cellular and non-cellular wireless communications standards at the same time. This means, however, that the subsystems must operate in very close proximity to each other within a single device (in-device coexistence). The resulting high level of reciprocal leakage can at times cause considerable interference. There is need for research work which will employ preliminary theoretical analysis, design and implement mechanisms and algorithms to avoid problems of in-device coexistence. Some objectives of the problem domain include bandwidth, Quality of Service and reduced cost. Some constraints of the problem domain include power conservation (mobiles devices are battery powered) and capability of the devices.

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G. *Quality of Service*

The significance of Quality of Service (QoS) is parallel with the recent evolution of telecommunication networks, which are characterized by a great heterogeneity. Many applications require a minimum level of assurance on QoSfrom the network. Popular applicationsare assured database access to retrieve information, inventory, e-banking, e-learning,e-medicine, remotely controlling robots in hazardous industries, applications for emergencies and security. Likewise, communication networks are also characterized by many levels of heterogeneity: portions managed by different Service Providers; various transmission means such as cables, satellites and radios; different implemented solutions such as ATM, IPv4, IPv6 and MPLS. In addition, a network may be heterogeneous also from the point of view of users, who can require different services and have a different infrastructure.

Present telecommunication networks are essentially composed of different portions and technologies: each single portion may implement a different QoS solution, whose algorithms to satisfy performance requirements may change together with the performance parameters. The ultimate challenge is to offer end-to-end QoS guarantees over such heterogeneous networks transparently to the users. Basically, QoS requests should traverse the overall network from the source to the destination through portions that implement different technologies and different protocols; QoS requests should be received and understood by each specific portion where QoS may have a different purpose and interpretation, which depend on used protocols and network features; QoSrequirements should be managed by control mechanisms suited for the objective; each single QoS solution is composed of layered architectures and each layer must have a typical role in QoS provision.

H. *Research Avenues*

The main motivation for the research idea proposed in this paper is to enhance utilization of all heterogeneous networks around us, with the following objectives:

- To maximize Quality of Service Delivery
- To utilize the maximum bandwidth providing network at any time
- To minimize the power consumption of mobile devices
- To minimize the cost of data access
- To minimize the health hazard due to radiations

The proposed research work would be an effective and practical approach for utilizing the best of network available around us at any point of time, based on the needs and requirements of our application. The outcome of such research work will give practical guidelines on the best network technology to access for various applications. The outcome of the research will provide an optimization between multiple objectives and constraints. Efficient utilization of available resources is the goal and motto of any system. Most of the Service Providers have agreements for sharing their resources/infrastructure, in order to minimize their investment while maximizing the benefits. In economic terms, the interoperability or integration of Heterogeneous networks offer the following additional benefits.

- Utilization of the best network at any instant of time.
- Additional revenues due to better Quality of Service.
- Avoidance and postponement of investments in new network / communication technology.
- Minimize interference among nearby networks.

Interoperability among heterogeneous networks will demonstrate several interesting outcomes in addition to establishing effective utilization. This approach has the ability to utilize the benefits of all networks in the vicinity. For example, the Cloud Radio Access Network has significant capability to strengthen LTE for handling the extraordinary data traffic faced by the present cellular mobile networks. Power conservation assumes great significance in the case of mobile devices as they are battery operated. Most mobile devices have many limitations in features like processing capability, storage level, screen size, resolution, battery back-up time, etc. Thus the outcome of the proposal will maximize the utilization of advantages of the mobile devices and the networks around us, while minimizing their disadvantages. The overall result will be satisfaction to the end user.

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III. HETEROGENEOUS NETWORKS

Wireless communication has become the technology of choice in our day to day life due to its convenience, competitiveness and availability. Design of rapidly deployable interoperable communication systems has gained significance due to the need for immediate response in situations like disaster recovery, relief after natural calamity, countering terrorism, communication among large gathering for one or two days (International Conference), etc.

Analysis of Bottlenecks and Improvement of Performance in Dense Wavelength Division Multiplexing (DWDM) based optical communication systems is discussed in [2,3]. Optical Communication has significant advantages like immunity to electro-magnetic interference (EMI), data security, high bandwidth over long distances, non conductive cables, elimination of sparks, ease of installation, etc. Both of the above communication mechanisms have their own set of limitations also.

A. *Early Day Radio Networks*

DARPA had started the Packet Radio Network (PRN) program [4], in 1972. In 1983, they deployed the Survivable Radio Networks (SURAN) [5] which used a small radio with low cost and power, with better scalability and refined packet radio protocols. In 1994, DARPA proposed the Global Mobile (GloMo) Information Program [6] to offer office-environment, Ethernet type multimedia connectivity anytime, anywhere for handheld devices. The Joint Tactical Radio System (JRTC) [7] with adaptive, multi band, multi-mode radios offered better flexibility over half-duplex single-channel radios at higher layers. JRTC can transmit and receive on different bands, using different waveforms and could be integrated with broadband transmission capabilities.

B. *Interoperability among Broadband Wireless Technologies*

As we move towards the next generation networks, one of the fundamental issues to consider is the integration of wireless technologies. Integrated networks will have impressive capabilities as well as cumbersome challenges in areas such as Radio Resource Management (RRM), Quality of Service (QoS), Security, Mobility, and Power Management. With the main objective of building an integrated WiFi–WiMAX network in a test-bed environment, The effects of integration on the QoS performance is investigated in [8].

C. *Heterogeneous Radio Access Networks*

The requirements for cooperation of heterogeneous radio access networks (RANs) are defined and a novel radio resource management (RRM) framework for support of mobility and QoS in a heterogeneous communication environment comprising IMT-Advanced and legacy systems is proposed in [9]. The RRM mechanisms are evaluated for the scenario of intra-RAN and inter-RAN user mobility. The RRM framework is further enhanced with computational intelligence based on fuzzy logic algorithms to enhance the process of handover.

D. *Cloud Radio Access Networks*

To meet the increasing traffic demand, a revolutionary wireless cellular architecture, referred to as the cloud radio access network (C-RAN), has emerged as a promising solution. A C-RAN consists of three key components:

- Distributed remote radio heads (RRHs) at remote sites of cells
- A pool of baseband units (BBUs) in a data center cloud
- A high-bandwidth low-latency optical transport network connecting the BBUs and RRHs

The challenges and recent developments in the technologies that potentially address the scalability issues of C-RANs are discussed in [10]. In particular, they focus on collaborative signal processing, resource management, and green architecture of C-RAN systems. They attempt to draw attention of the research community to the following important question: how to leverage the revolutionary architecture of C-RAN to attain unprecedented system capacity at an affordable cost and complexity.

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E. *Resource Allocation in Hetergeneous C-RAN*

Heterogeneous Cloud Radio Access Networks (H-CRANs) is proposed in [11] as a cost-efficient potential solution through incorporating the cloud computing into HetNets, to mitigate the severe inter-tier interference and enhance limited cooperative gains resulting from the constrained and non-ideal transmissions between adjacent base stations in HetNets. The vision set by 5G to achieve remarkable improvements in data capacity, delay reduction, and energy efficiency pushes the wireless research communities in both academia and industry to increase the density of base station (BS) deployments, particularly in urban areas, in order to provide better throughput and coverage performance. This densification is made possible by overlaying existing macrocell networks with cells of diverse sizes (i.e., microcell, picocell, femtocell, etc.) together with numerous radio access technologies, including Global System for Mobile Communications (GSM), code-division multiple access (CDMA), Long Term Evolution (LTE), and so on. The resulting interior interference in the emerging HetNets enforces inherent operational constraints resulting in a degradation of the network performance. To better manage wireless interference, BSs from different tiers are connected to a computing center (i.e., cloud) via wired/wireless backhaul links. This configuration forms the so-called H-CRAN. The advances and challenges in Resource allocation among heterogeneous cloud radio access networks is discussed in [12].

F. *The Road to 5G*

5G is expected to address the new and diverse demands, and foundational shifts needed, given a wide variety of applications and user, system, operational and business requirements. As 5G evolves, Network Function Virtualization (NFV) and Software Defined Networking (SDN) play a critical role as building blocks and roadmap for an increasingly user-centric and on-demand dynamic delivery, business-aware operation and service-oriented architecture in the fundamental paradigm shifts. Thus, NFV and SDN are leading the network transformation toward the future of 5G. Hence, 5G is expected to provide a service-oriented and business-agile environment, offering network on-demand and anything-as-a-service (XaaS), for a wide range of use cases and requirements, including enhanced mobile and immersive broadband and human-machine interaction with critical/low latency and massive IoT.

IV. INTEROPERABILITY IN HETEROGENEOUS NETWORKS

The mobile web traffic is growing rapidly due to service accessibility in densely populated areas and massive usage of smart hand held devices (smart phones, pads and Internet dongles). This is a challenge for mobile operators and service providers, because it forces systematically increasing network throughput capacity and in parallel to keep this investment on profitable basis. On the other side, the user satisfaction with mobile broadband service should be considered as well, in order to balance the user expectations and mobile operator investments.

Intensive competition between network operators as well as steady increase in mobile traffic calls for additional investments into the networking infrastructure. Keeping current mobile networks profitable, the following criteria should be satisfied: end-user quality expectations need to be fulfilled on the one hand and service quality over-provisioning should be eliminated on the other. This generates growing demand for adequate QoS estimation models accounting for dominant mobile data services.

The widespread deployment of Wi-Fi hotspots and wide area cellular networks opens up the exciting possibility of interoperability between these types of networks. Interoperability allows a mobile device to dynamically use the multiple net-work interfaces available to it so as to maximize user satisfaction and system performance. Three basic user profiles for the network users are defined in [13] and simulation studies demonstrate that dynamic switching on the basis of the user profiles of the mobile devices leads to higher network performance and increased user satisfaction. Careful design of pricing, billing and revenue sharing schemes is necessary to ensure the commercial viability of the multiple service providers involved in an inter-operable network setting.

The 802.11 or Wi-Fi is a low cost wireless access technology that supports low data rate within a short range. On the contrary, the IEEE 802.16 or WiMAX is a costly network that supports a data rate of 70 Mbps within the range of 50 km. To provide guaranteed and satisfactory service quality with moderate cost in wireless environment, integration of the two network technology is necessary. The difference in the MAC layer protocol and routing mechanism makes

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the interoperability of the two networks are challenging. The two most popular wireless networks IEEE 802.11 and IEEE 802.16 are explored with a view to examine the challenges and issues involved in the integration of both the networks in [14].

Several overlaid wireless networks such as 3G/4G/5G Cellular, Wireless LANs (WiFi), Wireless MANs (WiMAX), Mobile Ad Hoc Networks (MANETs), Wireless Mesh Networks (WMNs) and Wireless Sensor Networks (WSNs) may exist over the same geographical area. The requirement of interoperability among these heterogeneous wireless communication networks is of utmost importance. Spectrum conflict is the potential for competing technologies using the same frequency bands to interfere with each other to the extent that their performance degrades significantly when used within close operating range of each other.

The interworking of these diverse wireless technologies for efficient delivery of value-added applications and services lead to several challenging issues, mainly related to architectures, resource allocations, mobility management, QoS provisioning, and security. The various aspects of interoperability of heterogeneous wireless networks are defined and the concerns to be addressed are investigated in [15].

V. HETEROGENUITY IN NETWORKS

The heterogeneous nature of the various communication networks is a hindrance when we try to maximize interoperability between them. This is a challenge for mobile operators and service providers, because it creates hurdles in sharing the resources available with them and in parallel to keep their new investments under check. Overall, the customers and the mobile operators struggle to achieve maximum benefits by utilizing the best possible network technology, at any time for receiving highest possible bandwidth and providing service using the lowest cost technology, respectively.

Unlike Frequency Division Multiple Access (FDMA), only digital data and digital modulation must be used in Time Division Multiple Access (TDMA). Time Division Synchronous Code Division Multiple Access (TD-SCDMA) is suited for both symmetric and asymmetric traffic requirements for mobile internet access and multimedia applications. IP based “anytime & anywhere” data, voice, video and multimedia services are provided by 4G and beyond. Orthogonal Frequency Division Multiple Access (OFDMA) was chosen over TDMA and CDMA for 4G/5G, as Orthogonal Frequency Division Multiplexing (OFDM) can exploit multi-user diversity to increase the average spectrum efficiency.

The details presented in the tables give an idea of the level of heterogeneous nature of the various communication and network technologies. Table I presents the details of evolution of the various generations of mobile cellular telecommunication networks. A comparison of the metrics: data download rates and spectral efficiency for the various cellular network generations are presented in table I. Table II presents the combination of multiple access techniques with either Frequency Division Duplex (FDD) or Time Division Duplex (TDD) used by the various telecommunication systems. TD-SCDMA combines an advanced TDMA/TDD system with an adaptive CDMA component, operating in a synchronous mode. A comparison of the performances of the multiple access techniques TDMA, CDMA and OFDMA for various metrics is presented in table III.

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TABLE I. CELLULAR NETWORKS

Cellular Network Generation	Cellular Network Performance		
	Technology	*Data Rates*	*Spectral Efficiency b/S/Hz/Sector*
1G	Analog Cellular Telephony	-	-
2/2.5G	GSM / GPRS / EDGE	14.4 Kbps	0.5 to 0.6
3G	EVDO	2 Mbps	0.9
3.5G	HSPA	14.4 Mbps	1.1 to 1.4
4G	LTE / LTE-A & WIMAX	40 Mbps	5 to 8
5G	M2M / IoT	100 Mbps	> 15

TABLE II. RADIO INTERFACE

Telecommunication System	Scheme(s) Used
AMPS	Frequency Division Duplex (FDD)
CT2	FDMA / TDD
GSM	FDMA / TDMA / FDD
DECT	TDMA / TDD
TD-SCDMA	TDMA / TDD / adaptive CDMA
4G / 5G	OFDMA

TABLE III. TDMA VS CDMA VS OFDMA

Parameter	Multiple Access Technique		
	TDMA	*CDMA*	*OFDMA*
Network	2G / 2.5G	3G / 3.5G	4G / 5G
Cellular Reuse Factor	$\frac{1}{7}, \frac{1}{4}, \frac{1}{3}$	$\frac{1}{1}$	$\frac{1}{1}, \frac{P}{Q}$
Peak Power	High	Mid	Low
Average Power	Low	Very Low	Mid
QoS Assurance	Low	Mid	High
Resource Allocation Flexibility	Low	Mid	High

VI. CONCLUSION

Requirements of next-generation heterogeneous wireless networks provide ample opportunities for a variety of interesting and comprehensive research topics related to the concepts, methodologies, and techniques which support superior mobile value-added services. Thus, the development of new interoperable technologies: protocols, algorithms, architectures and applications will have an impact on the commercial deployment of wireless networks. Such networks may provide benefits to both customers and service providers. Futuristic wireless networks should be able to handle a large volume of multimedia information, having asymmetric data speeds in up and down links, having continuous

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coverage over a large geographical area, applying quality of service mechanism (e.g. efficient encoding, error detection and correction techniques, echo cancellers, voice equalizers), global roaming at low, affordable and reasonable operating costs. Communication among Heterogeneous networks should be seamless with regard to transmitting media and open regarding mobile terminal platform and service nodes, and provision of adequate security mechanisms. This will allow the usersto freely select the networks, protocols and applications. The service providers and content providers can extend their services and contents independent of operators. Network infrastructure, Location and charging information can be shared among networks and applications.

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