A Review on Integration of Software Defined Radios and Software Defined Networks

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Abstract: In this paper a survey of the research efforts invested in the analysis of programmable networks since late nineties is presented. This investigation is not limited to particular programmable networks but focused on also integration of programmable networks for upcoming wireless technologies, we are interested in proposals aiming effective use the frequency spectrum, considerably enhance network performance, cost effective and energy saving solutions for future wireless technologies. Hence, in this survey a review is presented showing how researchers have proposed solutions for these constraints using programmable networks and integration of programmable networks.

Index Terms: software defined radios (SDR), software defined networks (SDN), and integration, wireless technologies.

I. INTRODUCTION

Wireless communications have been enthusiastically adapted by people throughout the world. Cellular systems have experienced exponential growth over the last decade and there are currently around two Billion users worldwide [1]. Indeed, cellular phones have become an important part of everyday life in most advanced country. Future wireless technologies create a truly wireless environment. These technologies should be faster, with better quality, and are more secure. Most importantly, users can truly use network services anytime, anywhere.

This paper surveys programmable network and technical challenges. Since the literature focuses on isolated techniques SDN, SDR; we endorse the integration of those technologies, since they can work simultaneously and thus complement each other in order to support new applications and network services [2]. Integration of SDR and SDN will increase the amount of programmability on the network. Hence, this survey is structured as follows. First, we describe SDR & SDN separately. Next, we present integration of these technologies. Then, we discuss expectations, proposals and technical challenges for future wireless technologies. We conclude with future challenges for integration of SDR and SDN for the wireless communications.

SDR Technology: We are living in a rapid pace of communication technology. To go with this pace, communication systems require transparent insertion of the latest technological communication devices. The Software Radio Technology allows one to add new functionality without hardware changes; even during a technological update many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications. Software defined radios implement most of communication functions in software. SDR defined as “a radio in which some or all of the physical layer functions are software defined.”[26]. SDR allows a high degree of flexibility.

The reconfigurable SDR device is able to combine a software programmable processor and reconfigurable hardware components that can be reused for different applications [3]. Programmability in wireless data planes is implemented using SDR. Simplified architecture of SDR is shown in Figure 1. Analog to digital converter and digital to analog converters are implemented in hardware, while the modulation and demodulation are implemented using software. SDR technology has ability to update and change modulation schemes.

Figure-1. SDR architecture
Paper [4] summarizes the design and development of a portable software radio prototype which is built primarily using commercial off-the-shelf components and open source software. Their work demonstrates that today’s processors are capable of enabling a new generation of software radio in portable form factor devices. Table-1 shows comparison of traditional hardware based radios and software radio. The prototype device’s hardware comprises a reconfigurable radio enabling communication in multiple frequency bands, a host computer perform signal processing, a touch screen LCD and audio interface for display and user control, and a rechargeable battery for portable operation.

Table-1: Comparison of Traditional Hardware Based Radios and SDRs

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Traditional Radios</th>
<th>Emerging SDRs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Limited to the capabilities present in the initial design.</td>
<td>Much of the signal processing is done into S/W &amp; reprogrammable hardware.</td>
</tr>
<tr>
<td>2.</td>
<td>In any significant capacity cannot be reconfigured.</td>
<td>Can be reconfigured after deployment.</td>
</tr>
</tbody>
</table>

In SDR multi-hop reconfigurable network, the partition problem may occur when the software is broadcast. In paper [3] the CFSD scheme is proposed to solve this problem. In such a way, every node in the network can receive the software and update itself correctly. Power saving is one of the challenges in using SDR technology. Paper [5] presented a low-complexity low-power digital SL clock recovery algorithm, which is suitable for low power communication applications, i.e., biomedical devices and SDRs. The complexity, and power consumption and the results were performance was established in terms of mean square timing error (MSTE), computational compared with those of typical SL and feed forward clock recovery algorithms. In this paper authors have shown that the proposed method significantly reduces resource and power requirements, which makes it suitable for SDR.

Table-2: Comparison of previous SDR system and Labview based SDR system

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Previous SDR System</th>
<th>Labview based SDR system</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>Different software design flow for different components of system.</td>
<td>Common development software environment for all heterogeneous elements in SDR system.</td>
</tr>
<tr>
<td>22.</td>
<td>Components may lack a common abstraction layer.</td>
<td>Provides good abstraction layer.</td>
</tr>
<tr>
<td>3.</td>
<td>Results in complications and delays during system development and integration.</td>
<td>Provides tight hardware and software integration.</td>
</tr>
</tbody>
</table>

Bandwidth utilization is one more important issue on which researchers have focused their attention. A 1-GHz carrier frequency transmitter with a CDMA signal was implemented [6] on FPGA using pseudo parallel processing low-oversampling DSM and regular DSM, which increases bandwidth of the output signal four times without increasing the processing frequency while maintaining the same quality of output signal. One more cost effective approach is Lab view [20] based SDR tested aims at leveraging the heterogeneity of dense wireless deployments. Table-2 shows Comparison of previous SDR and Labview based SDR. In this section
we have discussed on some challenges such as reconfigurability, power saving and bandwidth and their solutions.

Thus, SDR is a modern radio communication system with the key-features that lead to software implementation of its components. SDR has been deemed as the future of telecommunications, as most radio devices are expected to be SDRs in the near future.

**SDN:** SDN is one key technology to operate next generation networks. Software-Defined Networking (SDN) is an emerging paradigm that promises to separate the network’s control plane from the data plane. SDN has ability to program the network. The idea of programmable networks since the late nineties is summarized in Table-3.

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Year</th>
<th>Programmable network</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1988</td>
<td>SOFTNET</td>
</tr>
<tr>
<td>2.</td>
<td>1990</td>
<td>Active Networking</td>
</tr>
<tr>
<td>3.</td>
<td>1995</td>
<td>OPENSING &amp; GSMP</td>
</tr>
<tr>
<td>4.</td>
<td>1998</td>
<td>IEEE P1520</td>
</tr>
<tr>
<td>5.</td>
<td>2004</td>
<td>4D Project and Soft Router</td>
</tr>
<tr>
<td>6.</td>
<td>2006</td>
<td>NETCONF, Ethane, SANE</td>
</tr>
<tr>
<td>7.</td>
<td>2010</td>
<td>For CES (parallel approach to SDN)</td>
</tr>
</tbody>
</table>

In Paper [7] SDN is explained in detail with its necessary interfaces and key attributes. This paper gives answer to the question of using SDN in a specific scenario. SDN simplifies network management. Using SDN new services and protocols can be deployed in future networks. SDN is a network architecture framework that decouples the network control from data plane which enables the network control to become directly programmable.

![Figure-2. SDN Architecture](image)

Figure 2 gives an idea about SDN system which separates control plane and data plane. Data plane consist of switching devices and control plane consists of SDN controller. The switching devices are used for forwarding packets, gathering and reporting network status. Comparison of SDN and Conventional Networking is shown in Table-4. In comparison, SDN encourages innovation by providing a programmable network platform to implement, experiment and deploys new ideas, new applications and flexibility [21].
Table 4. Comparisons Between SDN And Conventional Networking [21]

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Conventional Networking</th>
<th>SDN</th>
</tr>
</thead>
</table>
| Features   | 1. A new Protocol per problem  
2. Complex Network control | 1. Decoupled control and Data plane  
2. Programmability |
| Configuration | Automated Configuration with Centralized Validation | Error prone manual Configuration |
| Performance | Dynamic global control with cross layer information | Limited information and relatively static configuration |
| Innovation  | Easy software implementation for new ideas  
Sufficient test environment with isolation quick deployment using software upgrade. | Difficult Hardware implementation for new ideas, Limited testing environment, Long standardization process. |

Figure 3 shows the traditional networks where data plane and control planes are bundled together and SDN in which data plane and control planes are separated. Traditional networks reduce flexibility and limits innovation and evolution of the networking infrastructure.

Software-Defined Networking (SDN) [21] overcomes the limitations of traditional networking by separating the control plane and data plane.
Figure 3: Traditional networks and SDN network

Simplified view of SDN architecture shown in Figure 3(a). Control plane links are shown with dashed line. A few recent papers have surveyed specific architectural aspects of SDN [8, 14, 21, 23]. Flexibility and programmability are advantages of SDN. Along with advantages there are some new security challenges. Security solutions using comprehensive security architecture are designed in paper [8] to solve security issues. However, how to integrate this security architecture into current commercial networks such as carrier networks and mobile networks is not discussed. SDN supports dynamic nature of future network functions and applications. In [9] they have presented a discussion of a number of challenges in the area of performance, scalability, security, and interoperability. But Flexibility is one of the challenges. In the process, it can actually become more difficult to implement the higher level complex services needed by future networks. Paper [10] proposed a Network Hypervisor service that is capable of internetworking various SDN providers together. Network hypervisor enables the creation of virtual networks across multiple (heterogeneous) SDN providers, which will simplify the task of building and deploying complex network services over SDN. In paper [11] authors have analyzed the performance of two SDN architecture. From this analysis they have concluded that we can achieve SDN flexibility but it will lowers the performance and increases complex functionality. Paper [12] presented the current trends in traffic measurement in SDNs and highlighted their strengths and weaknesses and several challenges in it require further research. In order to meet the requirements of future wireless networks, mobile network architecture is empowered with SDN. Paper [13] introduces SDN into Frameless Network Architecture for next generation Mobile Network. Authors in paper [14] presented a comprehensive survey on SDN. They have not only provided an in-depth analysis of the hardware infrastructure but also identified cross-layer problems such as debugging and troubleshooting. They have discussed the main ongoing research efforts and challenges of SDN. Paper [23] provides a general overview of architectural techniques useful for building next-generation programmable wireless networks. Two SDN architectures [22] ForCES and Openflow follow the basic SDN principle of separation between the control and data planes; and both standardize information exchange between planes. However, they are technically very different in terms of design, architecture, forwarding model, and protocol interface.

In this section we have discussed on some issue related to SDN such as security, flexibility and work done by researchers to sort out that issues.

II. Future Wireless technologies

Nowadays different wireless [25] and mobile technologies are present. Wireless technologies are evolving from 1G to 4G. Table-5 shows comparison of generations of wireless communication.
Authors in [15] highlighted the key ideas for emerging technology and research challenges related to 5G system. Paper [16] introduced several emerging technologies that will define the future generations of telecommunication standards. Paper [17], [27], [28], [29] and [30] gives idea of development of 5G technologies.

III. Integration of SDR and SDN

The Integration of SDR and SDN will be deployed in order to access Future wireless technologies. Table-6 gives idea about requirements of future technologies and possible solutions to fulfill those requirements.

Table-5 Generations of wireless communication

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Technology</th>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bandwidth</td>
<td>824-894 MHz</td>
<td>850-1900 MHz</td>
<td>1.8-2.5 GHz</td>
<td>2-8 GHz</td>
</tr>
<tr>
<td>2</td>
<td>Speed</td>
<td>22.8Kbps</td>
<td>2Mbps</td>
<td>1Gbps</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Modulation</td>
<td>Analog</td>
<td>Digital</td>
<td>Digital</td>
<td>Digital</td>
</tr>
<tr>
<td>4</td>
<td>Services</td>
<td>calling</td>
<td>Email, SMS</td>
<td>Email, Wireless web access, Video and multimedia services</td>
<td>Video Chat, HDTV</td>
</tr>
<tr>
<td>5</td>
<td>Multiplexing</td>
<td>FDMA</td>
<td>CDMA, TDMA</td>
<td>W-CDMA</td>
<td>MC-CDMA, OFDMA</td>
</tr>
</tbody>
</table>

Table-6: Requirements of future technologies

<table>
<thead>
<tr>
<th>SR. No.</th>
<th>Requirements of future technologies</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Capacity and throughput improvement, high data rate</td>
<td>SDR</td>
</tr>
<tr>
<td>2</td>
<td>Improved energy efficiency</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Network densification</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Autonomous applications and network management</td>
<td>SDN</td>
</tr>
</tbody>
</table>

The main research associated with the Data layer includes both efficient operations of switching devices and utilization of transmission. Paper [18] explained important reconfigurable platforms development tools, and applications. They have tried to motivate consideration of reconfigurability as a discipline of engineering and as a field pursuit. Paper [19] develops an integrated architecture of NFV, SDR and SDN for 4G/5G mobile networks by considering the evolution of standards and emerging key technologies. NFV enables delivering...
network functions without installing hardware equipment, for every new service, making possible less investment in network equipment (CAPEX) and less expenditure on network management and operation (OPEX). It enables the standard network appliance to migrate from one hardware platform to another. By separating the system hardware architecture and functions, SDR can realize multiple functions via software based on a relatively universal hardware platform. It can program the operating frequency, system bandwidth, modulation, and source encoding. Moreover, the system can be easily updated by changing process modules. SDN allows telecom software developers to control network resources in the same simple way as ordinary computing resources. Hence the integration of SDR and SDN is solution to overcome the challenges of future wireless technologies.

IV. DISCUSSIONS

From the review of papers based on programmable networks we come to know some important points on which our research should focus. We can use cross layer controller in which the SDN Layer can be used to collect the information, and algorithms are applied to analyze the optimal allocation of spectrum and bandwidth, and then change the policy SDN Layer. The evolving wireless networks are envisioned to provide higher data rates, enhance end-user quality-of-experience (QoE), reduce end-to-end latency, and lower energy consumption. The different types of applications and usages demand different standards in wireless communication systems. Although all these systems have almost similar components, the ways these components behave differ greatly from standard to standard. Also, while migrating from one generation to next, wireless network operators face problems as the newer handsets may not be compatible with newer generation network. In this regard, a reconfigurable or reprogrammable radio is required that can show different functionality with the same hardware. As defined above, the Integration of SDR and SDN answers this requirement. High-security networking, spectrum and bandwidth utilization can be achieved by using SDR & SDN technology.

There are some applications such as viewing web pages which has large network traffic or video conferencing which require lot of bandwidth during a fixed period of time. To manage large network traffic or bandwidth utilization, SDN controller can be used. We will design algorithms to analyze spectrum and bandwidth utilization. Also we design algorithm to provide low power consumption. To solve security issue we can design algorithm such that the SDN Controller documents the frequency information and use conditions of each user.

Here we are considering one application such as Video conferencing in which we will integrate SDN and SDR. Basically Video conferencing provides connection between people in separate locations for the purpose of communication. For this transmission Video conferencing requires high speed and stable large bandwidth. However, the growth of video conferencing has depended heavily on the availability to run on a reliable digital communications network. Paper [24] explains the application and importance of video conferencing. Figure-4 gives idea of video conferencing.
In this type of communication we require to transmit the data which includes image, video, audio etc. for this application we require stable large Bandwidth. To fulfill this requirement we can use programmable networks. The integration of SDR and SDN will be best solution to manage large data traffic and bandwidth. Integration of SDR and SDN for Video conferencing is shown in Figure-5. In which data transmission can be controlled by SDR technology at data plane and traffic management and bandwidth utilization will be controlled by SDN controller at control plane.

![Diagram of Video conferencing by using integration of SDN and SDR.](image)

**Figure-5 Video conferencing by using integration of SDN and SDR. The solid lines define the data-plane links and the dashed lines the control-plane links.**

V. CONCLUSION

This survey paper discussed the issues related to programmable networks. The important points that this survey highlights are the challenges of future wireless technologies such as performance, power saving, security, and optimization problems, spectrum and bandwidth utilization, high data rate, reduced latency, network densification. Software- based implementations are better than hardware ones. SDN switching devices need more memory space and higher processing speed with an economically viable cost. Integration of various new hardware technologies is necessary. Researchers are working on these challenges. To overcome these challenges, integration of SDR and SDN is necessary. In this Paper we have discussed on one application Video conferencing. In which we have focused on points such as energy saving, security, high data speed.

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