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Software Defined Networking: Challenges and Consequences

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ABSTRACT
Network technology have always been a critical component of cloud computing's success. However, the sluggish development of a scalable IT infrastructure may result in competitiveness concerns. By adding additional functions to the entire network structure, software defined networking (SDN) can combat such difficulties. Administrators can encapsulate the underlying network architecture for applications and network services using SDN. The major findings of a systematic literature study on the challenges and consequences of SDN are presented in this paper. It reveals that the majority of publications discuss software defined networking implementation as a difficulty, citing issues such as vendor lock-in and the general danger of replacing existing network topologies. Security challenges originating from software defined networks are also discussed, as well as the end-constant user's high demand and anxiety of changing traditional networks. Another area of difficulty was recognized as issues involving specialized knowledge. The effects of SDN are examined by describing unique SDN features such as hardware-software decoupling and a global view of the entire network architecture. SDN has an impact on network administration as well, including changes in policy rollout, programmability, and network maintenance. Economic issues such as cost effectiveness and cost reduction are also explored.
Keywords — Software Define Network, Cloud Service, Internet of Things, Big Data, Virtualization

I. INTRODUCTION

Cloud computing, as an alternative to traditional computing technology, has emerged as one of the most important ICT topics in recent years1,2. As a result of the need for organizations to improve their performance through ICT, cloud computing has already changed their information infrastructure, associated business processes, and business models3.

Organizations are facing new issues as a result of cloud services, such as greater quality of service or high-security networking. Improved virtualization technologies are becoming increasingly important for meeting end-user expectations. To meet these demands, providers will need innovative solutions across this paradigm. Big cloud providers' services, such as Amazon EC2 or Microsoft Azure, are typically delivered to single organisations of various sizes, as well as private consumers, which can make distributing and controlling the required resources at the correct moment more difficult. From the customer's perspective, the significant increase in cloud service demand is accompanied with energy-efficiency and high-security requirements4.

The NIST definition of cloud computing6, which is now the most generally used definition5 of cloud computing, distinguishes between four deployment models: I private cloud, (ii) public cloud, (iii) community cloud, and (iv) hybrid cloud.Furthermore, the new word "inter-cloud" refers to a large-scale evolutionary leap from previous cloud deployment methods. A "cloud of clouds" or a "network of networks" can be used to describe it. Rapid elasticity is a major aspect of cloud computing, according to the NIST definition, which implies that there are no limits to the capabilities that can be provisioned within a single cloud. Increased usage ratios, on the other hand, lead to impending shortages, which can be avoided by pooling resources with other clouds. A more advanced information architecture is required to meet the NIST definition of cloud computing's claim of high flexibility, rapid scalability, and optimised resource usage. A software defined cloud architecture appears to be a good option to deliver appropriate solutions for the following trends and domains7,8 as a fresh and innovative approach:

- Cloud services: Organizations that have previously embraced public and private cloud services are now looking for self-service provisioning of their apps, infrastructure, and other ICT resources. This is a difficult task when you include in extra security, compliance, and auditing needs, as well as corporate reorganisations, consolidations, and mergers.
- Consumerization of ICT: Employees are increasingly using personal devices like as smartphones, tablets, and notebooks to access corporate applications, and ICT departments are faced with the challenge of securing corporate data and protecting intellectual property. The term "bring your own device" is commonly used to describe this trend (BYOD).
- Changing traffic patterns: Before providing data to the end user's device, today's applications connect to several servers across multiple enterprise data centres. This generates a significant amount of additional machine-

to-machine traffic, which must be delivered to linked devices at any time and from any location.

- Big data: More bandwidth is required to process huge datasets across thousands of distributed machines. Additional network bandwidth is required within and between enterprise data centres that are dispersed across the country.
- Internet of Things: The Internet of Things (IoT), which is just around the corner, will soon necessitate new infrastructure architectures as well as even more dynamic flexibility and scalability in order to analyse the expected volume of data and manage its distributed origins.

With these ever-increasing demands, businesses must be open-minded and reevaluate their approach to managing ICT infrastructure in order to remain profitable and cost-effective. As a result, network technology has become a critical component of cloud technology success9, but due to the slow development of a genuine scalable ICT infrastructure, this might lead to competitiveness issues4.

Software defined networking (SDN) can address network issues by adding new functions to the entire network topology, and thus "has the potential to enable ongoing network innovation and enable the network as a programmable, pluggable component of the larger cloud infrastructure," according to the report10. It "allows network operators and data centres to handle their networking equipment more freely using software that runs on external servers."11. Software defined networking is defined by the Open Networking Foundation as a dynamic, controllable, cost-effective, and flexible developing network architecture that is required for today's complicated applications7.Applications and network services can be abstracted from the underlying network architecture by administrators. The network management layer, which is often implemented in software, is separated from the data tier, allowing cloud services to self-adapt to changes in the network context12. SDN allows businesses to acquire a better understanding of where their workloads and data are stored. Using this knowledge, better decisions may be made about where data should be stored, removing the key security issues about public clouds previously mentioned.

The major purpose of this research is to use a comprehensive literature review to highlight the problems and implications of SDN on present network structures. The study begins with a discussion of the methodology used in conducting the literature review, followed by a summary of the major findings (section 2). The results of the literature review are discussed in detail in Section 3. Finally, in section 4, a conclusion is formed.

II. LITERATURE REVIEW: SOFTWARE DEFINED NETWORKING

In essence, a literature review reviews relevant literature for a particular subject of research. It establishes a solid foundation by reviewing what is currently known about a certain topic13. As a result, a literature evaluation opens up new avenues for future study and advancements in the relevant field14. The review's major purpose is to identify the approaches and concepts that have been utilized to study the effects and problems of SDN development.

2.1 Approach

The literature search was conducted using recognised and approved publications and databases for both information system and computer science studies. ACM (dl.acm.org), AISeL (aisel.aisnet.org), IEEE (ieeexplore.ieee.org), Science Direct (www.sciencedirect.com), and Springer Link are among the databases and journals used (link.springer.com). The search field's time range was limited to years beginning in 2010. Because the phrase software defined networking, and notably its acronym SDN, was used for different topics before to 2010, search queries prior to 2010 did not provide relevant results. Between June 1st and June 15th, 2014, all search queries were attempted.

The fundamental goal of the literature review was reflected in the keywords. As a result, the following keywords were created and utilised to find relevant papers and proceedings: I the "software defined networking" challenge, (ii) the "sdn" challenge, (iii) the "software defined networking" impact, (iv) the "software defined networking" impact, (v) the "sdn" evolution, and (vi) the "software defined networking" evolution.

The second step's major goal was to locate appropriate papers for the literature review. The method selected was to scan all abstracts from published journals obtained by conducting a search using the required keywords. The selected articles were kept for the following phase after studying the abstracts and deciding whether or not they were relevant.

The initial search results for each database with the defined keywords were as follows: ACM (found: 824, relevant: 11), AISeL (found: 50, relevant: 0), IEEE (found: 1290, relevant: 33), Science Direct (found: 241, relevant: 12) (www.sciencedirect.com), and Springer Link (found: 241, relevant: 12). (found: 108, relevant: 5). There are various explanations for the large number of detected articles compared to relevant articles. Each keyword was looked up separately (i.e. each database was queried 6 times). As a result of the overlapping results from numerous keywords, several articles displayed many times during the search query. The doublets were taken out. Second, the majority of the articles described and specified advanced statistical and mathematical technologies that were unrelated to the study's goal. Furthermore, because SDN can be an abbreviation for various topics such as "Supply and Demand Networks" or "Shareware Distribution Network," numerous articles discussed an entirely other topic. To determine whether the articles were relevant, every title and abstract of the articles retrieved was scanned and critically evaluated to see if the content was relevant to the research topic. A total of 61 articles were found to be relevant.

Following that, each of the 61 articles was thoroughly examined and a first concept matrix was created. In that matrix, the methods utilised, the basic idea, the conclusion, and the final classification – whether relevant or not – were also noted. An additional rigorous selection procedure took conducted during the transfer of the items into the concept matrix. As a result, a few articles were deemed irrelevant. The reason for this is that the abstract designated "software defined networking" as the article's main focus, but it also covered a lot of ground that wasn't relevant to the review. In the end, the literature evaluation comprised 44 articles. The appendix contains the final concept matrix. Finally, categories and concepts were defined based on the final concept matrix, and are discussed in detail below.

2.2 Main Results of the Literature Review

Since 2011, the demand and need for research on SDN, as well as its problems and impacts, has increased, according to the review. After finding no relevant articles in 2010 and one relevant item in 2011, the first increase occurred in 2012, with seven relevant articles. In 2013, 22 articles dealt with the challenges and implications of SDN, while 14 articles dealt with the topic again in the first half of 2014. SDN is becoming more relevant over time, as evidenced by the temporal analysis, with more study and analytical methodologies predicted in the next years.

Figure 1 depicts a summary of the discovered SDN problems and impacts. The majority of studies discuss implementation as a challenge. This category includes factors such as vendor lock-in and the high risk of changing established network topologies, which are frequently debated and explored. The category of demand is ranked second in terms of attention given. Security challenges coming from software defined networking, as well as the end-constant user's high demand paired with the fear of altering old networks, fall into this category. The third category covers the subject of existing software defined networking know-how. This category included the administration and control of software defined networks with current workers, as well as the overload that resulted.

Figure 1 also demonstrates that in the publications examined, the distinctive aspects of software defined networking are discussed the most. This category includes elements such as separating hardware from software and a global view of the entire network architecture. When describing the consequences of software defined networks against traditional networks, the second category – management – is crucial. This main area includes easier policy implementation, network programmability, and network maintenance. Last but not least, there are economic issues to consider, such as cost efficiency and cost reductions for specialized and skilled personnel. These tendencies indicate that current research is mostly concerned with technical and scientific issues.

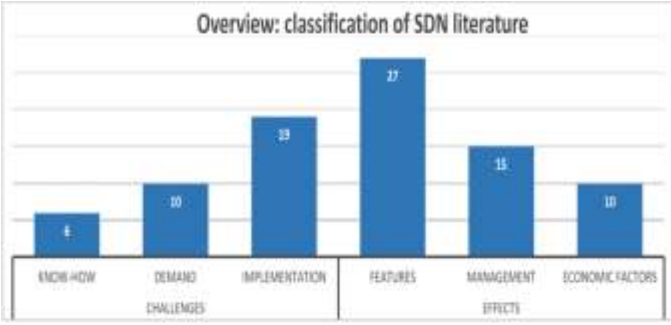

Fig. 1. A summary of a number of publications addressing the issues and consequences of SDN.

III. DISCUSSION OF RESULTS

The problems and consequences found through the comprehensive literature review are discussed in depth in this section.

3.1 Software Defined Networking: Challenge – Know-How

According to the literature, software defined networking faces a significant barrier in terms of present data centre know-how. According to Caraguay et al., implementing SDN in an enterprise necessitates determining the topology and location of these controllers in order to estimate the required number of controllers. Furthermore, a lack of expertise might result in a high security risk, as a software defined network's centralised controller is more vulnerable than traditional networks15. When such architecture is managed by unskilled personnel, Patouni et al. uncover comparable issues. They state that maintaining network operation necessitates a migration plan and a well-thought-out roadmap in order to eliminate single points of failure16. Casado et al. acknowledge that software defined networking has the ability to address issues like vendor lock-in and difficult management that plague traditional networks. However, because this technology has not yet evolved, present operators are faced with considerable complexity rather than easy administration and network architecture building17. Another point of view is that while software defined networking may be a well-established standard in some enterprises and industries, implementing it still necessitates a completely new pool of know-how on the operators' side, as well as additional overhead to meet current devices in current networks18,19. The placement of middle boxes in choke points and the management of traffic isolation in networks20 are two specific instances of essential know-how. Because the decoupling strategy was primarily designed for large businesses, Caraguay et al. assume that software defined networking is difficult to adapt to smaller networks with a lack of qualified people. As a result, unexpected interactions with other deployed networks may occur, resulting in an increase in broadcast traffic from non-OpenFlow compatible devices15.

3.2 Software Defined Networking: Challenge – increasing Demand

When it comes to new technology, Akyildiz et al. cite many barriers to rising demand. For example, the rapid rise of cloud computing21 has necessitated the need for an appropriate and specific service for a variety of traffic types, such as video conferencing or online browsing in a very short time frame, as well as the requirement for greater resource efficiency for higher system performance. Galis et al. concur with these concerns, stating that user demand is never-ending but rather continually expanding, necessitating the consideration of software defined networking22. Despite the strong demand, today's coupling of infrastructure and design in traditional networks entails a major shift in the current topology, which comes at a hefty cost for both vendors and enterprises. New criteria for mobility, server virtualization, and cloud computing must be met to fulfil the growing demand – particularly in terms of quality of service and security concerns. As a result, software defined networking is still lacking, and the centralised controller is unable to meet demand due to the network's negative compromised resilience23,24,15. According to Bhattacharya and Das25, one of the essential factors associated to the internet is quality of service, which must handle rapidly changing requirements and dynamically dispersed policies. Providers in the field of software defined networking now have a holistic view of the entire infrastructure and may thus address the aforementioned difficulties. However, present equipment will not be able to handle the increased demand, forcing a costly investment in new technology. This, according to Raghavan et al., is the current embargo on the development of software defined networking24. According to Patouni et al., since the number of proprietary hardware appliances has grown dramatically, management has faced significant obstacles in launching new network services. They go on to say that the Internet of Things is a contributing reason to the rise in needs. Even if software defined networking is proving to be a viable option, there are still challenges to overcome, such as automation speed or isolation, in order to achieve high performance in the above-mentioned needs.16 Costa-Requena describes software defined networking in LTE mobile networks with a specific example. The enormous demand for new devices necessitates investment in new technologies, yet software defined networking merely "appears" to be a crucial enabler in the development of new telecommunication infrastructure26.

3.3 Software Defined Networking: Challenge – Implementation

One of the most significant issues is implementing software defined networking in traditional networks. Despite its achievements thus far, SDN adoption is still in its early stages10. The writers agree that the intricacy of the new technology is one of the primary causes. Only some of these speed, scalability, security, and/or interoperability issues might be solved with existing research and industry solutions4. Galis et al. identify the challenge of incorporating new technology without having to redesign the entire architecture, including all of its characteristics and related components22. This viewpoint is shared by Cahn et al., who consider the lengthy implementation schedule to be the most significant disadvantage27. Unexpected interaction with other deployed networks, integration with legacy networks that do not support the OpenFlow protocol, fundamental errors when emulating software defined networking beyond certain limits, architectural updates and deep changes in inter-domain routing protocols, service models, and operating procedures15,28,29,18. Lu et al.30 and Caraguay et al.15 point out that, in addition to technological problems, businesses have cost constraints, because software defined networking necessitates a full deployment of "SDN-enabled" network switches as well as a thorough re-engineering of the entire network topology. For most businesses and organisations, the risk of implementing software defined networking (despite the numerous benefits) is now too great. Because software defined networking is particularly vulnerable and the firewall can be bypassed by introducing purposeful flow tables31,32,15,33, security considerations play a crucial role in this instance. However, even if software defined networking faces significant hurdles during deployment, the benefits that result (such as scalability and reliability) warrant a strategy and future trials with applications for improving data centre network management34,35.

3.4 Software Defined Networking: Effect – Features

When compared to traditional networks, software defined networking has a number of new features. The ability to decouple the forwarding plane from the data plane, resulting in many abstraction layers36,37,10,38, is the most prevalent and most frequently stated feature in the literature. When compared to tight standard network models39,11, Azodolmolky et al. regard this as innovative. This situation leads to data plane programmability (which allows for forwarding table modification), network customization (such as data centre interconnections), and centralised control decisions due to a global view of the entire network40,41,21,42,43. The OpenFlow protocol, according to Natarajan et al., is an increase in network visibility44. Kirkpatrick also sees the offered API as a benefit provided by software defined networking that allows users to easily manage applications (such as e-mail or telephone applications) throughout the entire network45. Software defined networking45,46 also defines dynamic, demand-based network segmentation and utilisation as critical essential aspects. The overhead on per byte transfer is greatly reduced when the header information is further optimised by employing dynamic flows rather than static routing47. Dely et al. describe an SDN-based architecture for optimising wireless LAN handover mechanisms48. SDN is defined by Vissicchio et al. as a novel architecture that allows for the control of the entire network structure while also providing the benefits of innovative and improved management49. Azodolmolky et al. list seven important traits that go along with the major features discovered in the literature39.

3.5 Software Defined Networking: Effect – Management

The primary purpose of good network administration is to coordinate a variety of methods, tools, and activities in order to provide high quality to the end user. Software defined networking does this through a variety of means, including increased network utilisation and simplified management via software-controlled hardware50,51,41. Today's dilemmas would include fast expansion of cloud services and the need for a suitable and specific service for different traffic types in a short time frame – as Akyildiz et al. point out, software defined networking provides a global view of the entire topology, allowing for efficient management21. Because of the increased demand, a separate common management plane52,39 is required for easier management. Operators will confront even more issues as the influence of SDN grows, such as greater storage. Virtualization, allocation, and migration are only a few of the many resources that will make up the future network architecture. Management using software defined networking will play a crucial part in the creation of a new ecosystem. SDN is the most significant networking breakthrough in the last two decades, combining the fundamental ideas of network programmability, automation, and orchestration41. A software defined network, unlike traditional networks, is not reliant on "dumb" devices making decisions, but rather on a centralised controller that allows for rapid deployment and global decisions. Software defined networking will have a significant and beneficial impact in this instance.

3.6 Software Defined Networking: Effect – Economic Factors

Software defined networking has a lot of potential for increasing efficiency while lowering costs and complexity53,54. Today's cloud computing requirements are surging, necessitating lower energy consumption and more secure networking21,4. Lombardo et al. detect a significant potential for dynamic distribution of network services over network nodes when compared to traditional networks, but the testing, experimenting, and launching procedure is currently too time intensive and incompatible with business needs55. At this stage, Casado et al. state that current networks are too expensive and hard to manage17.

IV. CONCLUSION

Although software defined networking is considered as a paradigm change, it nevertheless confronts a number of obstacles. The obstacles and impacts covered provide a broad overview of what may stymie further development and what is attainable when technology is successfully integrated.

The lack of know-how, combined with the high complexity of integrating into traditional networks, are the key reasons behind the technology's slow adoption. Furthermore, the majority of the articles examined describe software defined networking in great detail on a mathematical and technological level, making it difficult for businesses and organisations to determine whether the technology can have a specific commercial impact (e.g. on increasing efficiency or reducing costs). Nonetheless, as the number of users and their needs grow, providers will need to rethink how they use current network technology in order to remain competitive and profitable. As the literature research found, separating the control and data planes has numerous advantages, including better management, increased functionality such as dynamic virtual network deployment, and cost savings. These advantages, in addition to presenting the technical aspects, should play a key role in future study, particularly in the IS sector.

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