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On National Research and Educational Networks

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Abstract. National Research and Educational Networks (NRENs) provide vibrant services for the research and education community. The services mainly focus towards increasing mutual collaboration and resource sharing. This eventually leads to better resource utilization and enhances research quality. However, the maturity level of NRENs varies from country to country. In this paper, we inspect the current status of the NREN in the Kingdom of Saudi Arabia (KSA). We have found that there are two Saudi organizations having connections with global NRENs, namely, King Abdullah University for Science and Technology (KAUST) and King Abdulaziz City for Science and Technology–Internet Services Unit (KACST-ISU). The first organization (KAUST) was the first university in KSA to have the global NREN connection in 2011. The second organization (KACST-ISU) had its first connection in 2016 and it is an Internet Service Provider (ISP) for approximately 50 different organizations in KSA. We have used various statistical tools to compare the two organizations, including statistics concerning the amount of incoming and outgoing traffic towards global NRENs. We found out that more than 95% of the KSA traffic exchange is between KAUST and global NRENs. We hope that the research conducted herein helps in providing a better overview of the current status of potential KSA research and educational network(s). Also, we hope this research will enlighten the path for a better NREN implementation in KSA in the near future.

Keywords: NREN, Saudi Arabia, Internet, Incoming/outgoing traffic, Service Provider, Statistical tools.

1. Introduction

The importance of building reliable computer networks gained a dramatically increasing significance in the past decade. With the huge advancement in computer hardware and software systems and with the introduction of smart phones and tablets; more services and applications are being digitalized. This, so called digital transformation, plays an important role in improving the quality of life for our humankind. Almost everything in contemporary life is changing; commerce, education, health care, gaming, ..., *etc*.

The aim of this work is to introduce and try demystifying a special kind of networks called National Research and Educational Networks (NRENs). In particular, a special focus is directed to the narrow topic pertaining to the current status of this kind of networks in the Kingdom of Saudi Arabia (KSA). We think that this is the first time this narrow topic is addressed in the open literature. In fact, our attempts to collect data and gather information on this topic proved to be a formidable and challenging task, indeed. So, we have dutifully taken the responsibility to trace all what has been written on establishing an NREN national

project for Saudi Arabia. We hope that our efforts will be fruitful for enlightening the path for other researchers to carry on further and build upon our current work.

We start the remainder of this paper with a short historical exposition about the beginnings of the Internet in Section 2. This is followed by Section 3, which covers the status of the Internet in KSA and highlights its potential and motivations. In Section 4, we give a brief introduction about NRENs worldwide in general, and identify their names, structures and roles. Section 5 covers the status of a proposed NREN in KSA. In Section 6, we present the methodology and tools used in the present work. In Sections 7 and 8, respectively, we present and discuss the various results produced by our analysis or extracted from the data collected. These are followed by the conclusions in Section 9.

2. The Internet History

The history of computer networks goes back to the 1960s, when there was a growing need for the government researchers in the United States of America (USA) to share information. Computers at that time were large and difficult to move[1]. In order to store any bit of information in any single computer, one had to either travel with a magnetic tape or send it by the postal system. Figure 1(a) shows the IBM 350 Disk Storage Unit that was rolled out in 1956 to be used with the IBM 305 RAMAC to provide storage capacities of 5, 10, 15 or 20 MB (Mega Bytes). In Fig. 1(b) we can see the huge improvements in data storage of up to 1 TB (Terra Bytes) in a microSD card of a fingertip size in 2019.

The cold war that continued for most of the second half of the twentieth century between the former Soviet Union and the USA was another incentive for the emergence of the Internet. The USA Department of Defense (DoD) needed to find ways for information transfer that works reliably even after a nuclear attack[2]. That need eventually led to the formation of the Advanced Research Projects Agency Network (ARPANET)[3]. The network evolved to a global network of networks worldwide, which is what we know as the Internet nowadays. The definite article and the upper-case initial letter in the noun ‘the Internet’ emphasize that it is a unique and recognizable entity and distinguish it from many other networks of networks, each of which is called ‘an internet’.

On January 1983 a new communications protocol was established called the Transfer Control Protocol/Internetwork Protocol (TCP/IP)[4]. This protocol constituted a code or etiquette of communication rules that allowed computers of different kinds on different networks to communicate to each other. Prior to 1983, computers did not have a standard way for communication. Birth of the Internet might be considered to have taken place on the 1st of January 1983, when the DoD and ARPANET officially changed to the TCP/IP standard[4]. Now all computers from different networks worldwide can communicate in a common language.

3. The Internet History in Saudi Arabia

In 1993, the Internet was introduced into the Kingdom of Saudi Arabia (KSA) for the first time as a 9.6 kbps link to the Collage of Computer Science and Engineering (CCSE) at King Fahd University of Petroleum and Minerals (KFUPM)[5]. In 1994, King Abdulaziz City for Science and Technology (KACST) started the national (.sa) domain management to coordinate Internet services within the Kingdom[5]. In 1995 KACST used a 64 kbps link from King Faisal Specialist Hospital (KFSH), which was then connected to Baltimore’s Johns Hopkins Hospital (USA) for tele-medicine and health education over a T1 line 1.5 Mbps link[5]. In 1998, the Internet

Services Unit (ISU) was created as a separate department within KACST and it was made responsible for providing Internet services in the KSA in cooperation with a set of telecommunication providers from the private sector[6]. This set of providers was comprised initially of the Saudi Telecom Company (STC), and was later enlarged through the addition of other companies. The KACST-ISU had two points-of-presence (PoPs), one at Riyadh and the other one in Jeddah. In 1999, the Internet was made officially debuted and launched for public access in Saudi Arabia.

The Internet in Saudi Arabia is regulated and supervised by the Communications and Information Technology Commission (CITC). The number of Internet users was 200 thousand in December 2000, and it increased by 1170% to be 2.54 million in 2005[7], and continued to experience dramatic increases since then. Hence, Saudi Arabia is considered as one of the fastest growing Internet markets. In 2006, some major changes were made to the Internet infrastructure in the KSA. These major changes included:

- The movement of the task of handling the Saudi Domain Name System (DNS) to the *Saudi National Information Center (NIC)* as a part of the CITC,
- Assignment of filtering to the ISPs side, with the filtering list being provided by the CITC, and
- Connection of the ISPs to the Data Service Providers (DSPs) rather than to the KACST-ISU.

The CITC issued licenses to three DSPs to provide the commercial gateways to the Internet in 2006, namely the Saudi Telecom Company (STC), Bayanat Al-Oula (later acquired by Mobily) and the Integrated Telecom Company (ITC). Table 1 represents the CITC definition of the different types of service providers[8]. Figure 2 shows the timeline for the Internet evolution in the KSA.

In 2018, the number of subscribers in KSA for mobile telecommunication services were 41.31 million, while the number of fixed telecommunication subscribers were 3.12 million[9]. For the broadband subscribers in 2018, the mobile broadband subscribers were 29.15 million while the fixed broadband subscribers were 1.90 million subscribers [9]. The telecom revenues on 2018 were about 73.3 billion Saudi Riyals[9].

4. National Research and Educational Networks

A National Research and Educational Network (NREN) usually refers to the organization that designs, builds or leases, operates, maintains, supports and manages a physical network for the benefit of the research and education community. In reality, the NREN physical network is usually a "private network" or a "closed network" dedicated to the education and research community. The physical NREN connects education and research institutions directly to each other, to other NRENs and to the Internet. There is one NREN almost in every country, although some countries may have specific networks for different research and educational sectors, such that the maturity or sophistication level varies from one network to another. Also, NRENs have different names, for example, the NREN in the USA is called *Internet2*, while in Japan it is called *Science Information NETwork* (SINET). Figure 3 represents the USA Internet2 topology, while Fig. 4 shows the Japanese SINET network topology, and Fig. 5 demonstrates the topology of Australia's Academic and Research Network (AARNet). The need for creating NRENs is not new, and many NREN establishments were introduced in the past few decades. In the following, we list some of the

early NREN implementations, which are predecessors for modern NRENs:

- UNINETT in Norway, established in 1976.
- Computer Science Network (CSNET) in 1981 and later NSFNet in 1985 in the USA.
- Joint Academic NETwork (JANET) in the UK in 1984.
- Swiss Education and Research Network (SWITCH) in 1987, and
- NORDUNet for the Nordic countries in 1988.

National research and educational networks might be connected with each other forming a larger network of NRENs, such as the pan-European network (GÉANT) or the Asia-Pacific network (TEIN3) (See Fig. 6 and 7, respectively). There are many reasons for having a NREN in every country; some of which include[10]:

- **Collaboration and cooperation**: Research and education communities are small in size and scattered. So, building an infrastructure for collaboration and cooperation will increase the level engagement and improve the quality of research. It will also enhance inter-disciplinary and inter-regional research, as well as allow large research projects that demand the participation of a huge number of researchers. One of the important applications is surgical education through the transmission of live surgeries[11]. Also, the floor is widely open for developing tools to preserve the medical information system[12]. Moreover, the aforementioned collaboration translates directly into partnership between academia, industry, government and the private sector.
- **Knowledge contribution**: Distinguished researchers and talented educators are scarce resources. Providing a platform for knowledge sharing is going to be beneficial for all members of the research and education community. In addition to the large contribution from the research community to the NREN itself, researchers offered a modern Software-Defined Networking (SDN) deployment for GÉANT[13] and for GÉANT SDX[14]. A beneficial work for links load distribution using SDN and traffic forecasting could be used by NREN operators for better traffic handling[15,16]. Also, researchers can add significant contribution in the field of security[17] and even they can extend the underlying paradigm using artificial intelligence[18].
- **Resource sharing**: The infrastructure, services and applications required for advanced research are very costly to provide and would require substantial investment. Also, various members of the research and education community do not have the necessary or the same financial support or purchasing power. Therefore, it is really prudent for researchers and educators to share resources, and for the ones among them with extra funds to offer some aid to the tight-budgeted ones. An example of resource sharing is the Global Environment for Network Innovations (GENI), funded by the National Science Foundation (NSF) in the United States of America. This GENI enables researchers to have a virtual laboratory and to obtain computational resources from locations around the United States for networking

and distributed systems research and education[19].

An example of a successful NREN is the Internet2, which is a member-driven advanced technology community founded by the USA leading higher education institutions in 1996. Internet2 is a non-profit consortium led by more than 300 US universities working in partnership with industry and 60 government agencies[20]. The primary goal of Internet2 is to develop advanced computer network applications to facilitate teaching and research. The Internet2 Network Operations Center is powered by Indiana University and it is a project of the University Corporation for Advanced Internet Development (UCAID).

Every node on an NREN can be thought of as a potential *Service Provider* (SP) that provides solutions and/or services to end users and organizations. Service providers are responsible to provide reliable services for their clients 24 hours a day, 7 days a week, all year round. This is a crucial responsibility due to the increase in demand and dependency on online services. Service providers need to take a good care in designing their infrastructure to reliably scale and support clients' demand. Also, SPs need to have good visibility and control over their infrastructure. The reliable design of the SP infrastructure increases customer satisfaction and improve service availability.

5. National Research and Educational Network in Saudi Arabia

National research and educational networks provide vital services for the research and education community. It is very important to plan it very well so that its structure is becoming highly reliable and easily scalable. Mainly, NRENs are formed by connecting universities with each other. Also, in most active countries having NRENs there is a governmental financial support for such national network to encourage collaboration in the educational and research sectors. Therefore, we select the governmental universities in KSA as the starting point for the present NREN study. At a later stage, other research and educational establishments in KSA (including private universities and colleges as well as military colleges and secondary schools) might be included.

Saudi Arabia witnessed a dramatic increase in the number of governmental universities in the past decade, and this number has reached 28 in 2020. Table 2 shows a list of all these universities and some additional information about each of them. The information in the table were not readily available and had to be collected and consolidated from various sources[21–24]. In order to have a better visualization of the situation, Figure 8 shows a geolocation representation for the universities listed in Table 2. Also, the figure shows the universities as allocated to the 13 different KSA regions.

Early proposals for a National research and educational network (NREN) in KSA have appeared in a concealed way. It was difficult to collect the information from various resources on the Internet to have a better understanding of this project. The first trace for such proposals was found on the resume of Dr. Mishal Al-Kadhi, a prominent KACST officer. Dr. Al-Kadhi states in his resume that around 2005, he worked on the project named *Saudi NREN* while he was the director of KACST-ISU. The same project appeared again in 2009, within some documents of the same organization (KACST-ISU), albeit with a slightly different name as the *Saudi Academic Research and Educational Network (SAREN).*

In 2009 King Abdullah University of Science and Technology (KAUST) was founded in Thuwal, Saudi Arabia. This university received governmental support that

was admirably generous and virtually unlimited. As a consequence, it was the first university in the KSA to have a connection with the GÉANT network as early as 2011[25], which was known as SARInet, an abbreviation for the Saudi Arabian Research and Education Network. In addition, KAUST had another link with the NORDUnet, of the five Nordic countries; Denmark (DeiC), Iceland (RHnet), Norway (Uninett), Sweden (SUNET), and Finland (Funet). Since then, KAUST researchers have been very active and have been able to significantly utilize their connections with global NRENs.

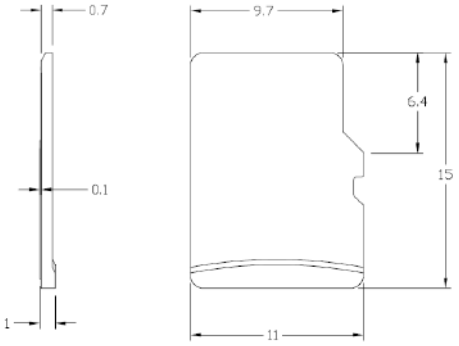
On 21 September 2017 KACST-ISU announced the launch of the Saudi Research & Innovation Network. This network was called MAEEN, a transliteration of the Arabic word (معين), which means a renewable (non-depletable or non-exhaustible) source. Furthermore, KACST-ISU established two connections for MAEEN with two of the most important NRENs worldwide. The first connection was established with Internet2 and the second connection was set up with GÉANT[26]. Table 3 summarizes the historical development of NREN projects in Saudi Arabia. It is important to keep in mind that the initial role of KACST-ISU is that of an ISP.

(source: https://www.ibm.com/ibm/history/exhibits/storage/storage_PH0350A.html)

(source: https://drtomcrick.files.wordpress.com/2011/12/5mbharddrive1956.jpg)

(a) IBM 350 Disk Storage Unit up to 20 MB of storage (1956).

(source: https://www.cined.com/content/uploads/2019/05/1TB-microsd-featured.jpg)



(source: https://datasheet.ciiva.com/26814/getdatasheetpartid-143101-26814490.pdf)

(b) SanDisk microSDXC 1 TB of storage (2019).

Fig. 1. Data storage devices.

Table 1. CITC definition of different types of service providers in Saudi Arabia.

Acronym	Definition
Facilities-Based Provider (FBP)	Facilities-Based Providers in Saudi Arabia are service providers who own network infrastructure and hold individual licenses in accordance with the Telecom Act. They are licensed to operate a public telecommunications network and provide fixed voice telephone services, public mobile cellular telecommunications services, fixed and mobile data communications services.
Data Service Provider (DSP)	Data Service Providers in Saudi Arabia are service providers who own network infrastructure and hold individual licenses in accordance with the Telecom Act. They are licensed to establish wired and wireless networks in the Kingdom for data services.
Carrier Service Provider (CSP)	Carrier Service Providers in Saudi Arabia are existing public utility providers such as electricity, water and railways that have communication facilities (optical fiber cables or towers) in the Kingdom to lease surplus capacity within their facilities to facilities-based telecommunications service providers (FBPs) that are licensed by the CITC to provide fixed and mobile communication services in the Kingdom of Saudi Arabia. This license does not permit an FBP to provide any other telecommunications and information technology service whatsoever.
Internet Service Provider (ISP)	Internet Service Providers in Saudi Arabia are holders of Class B licenses which do not allow them to own network infrastructure. Instead, they lease capacity from FBPs or DSPs to connect both to the end users and to the Internet. In particular, they can provide dialup and broadband Internet access, email, IP allocation and assignment, web design and hosting, network monitoring, DNS registration, Internet content publishing, Internet advertising and other services.

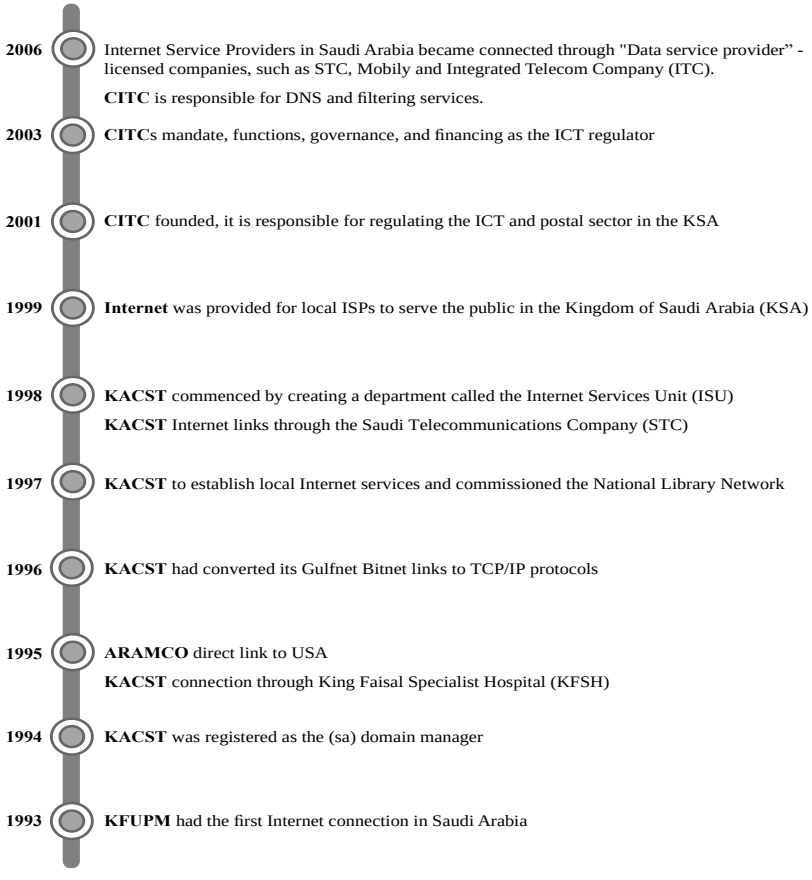


Fig. 2. The Internet history major milestones in Saudi Arabia.

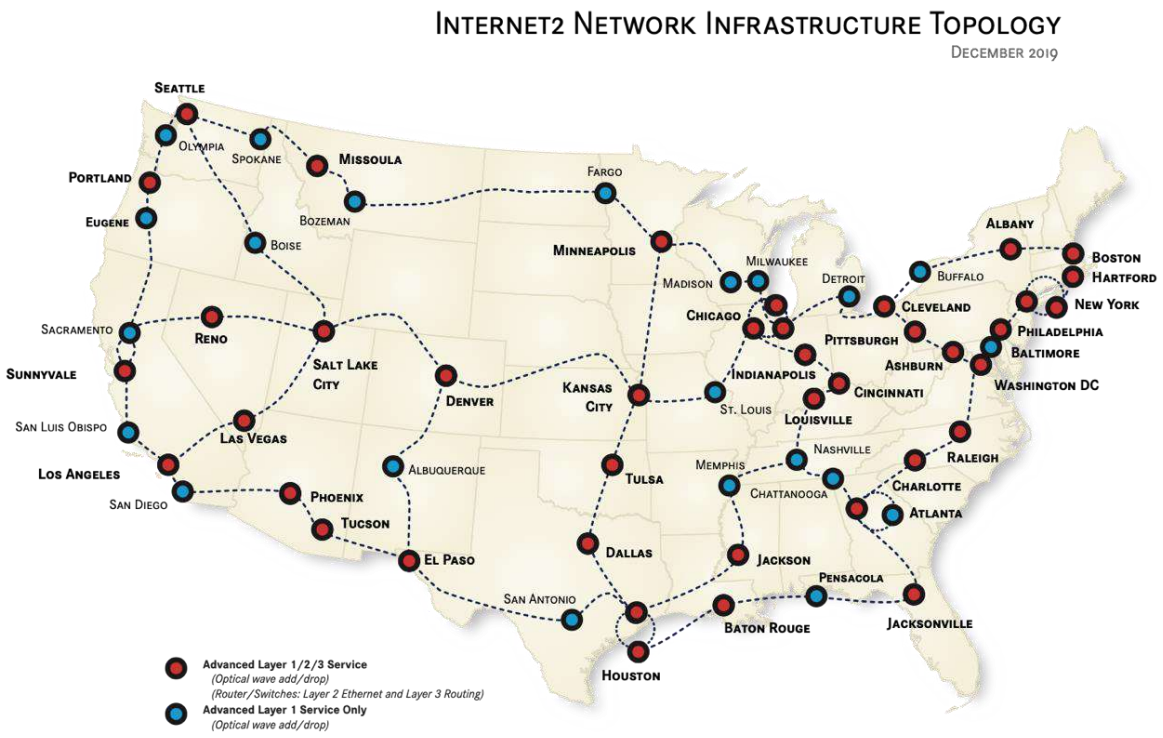


Fig. 3. USA's national research and education network (INTERNET2).

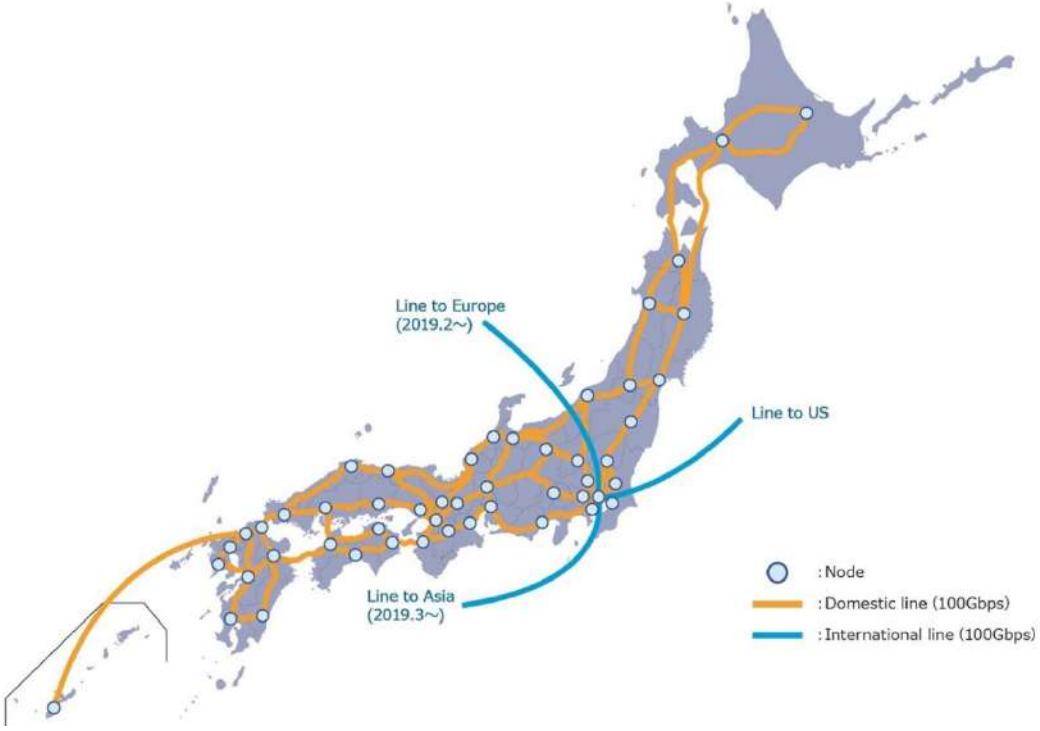


Fig. 4. Japan's national research and education network (SINET).

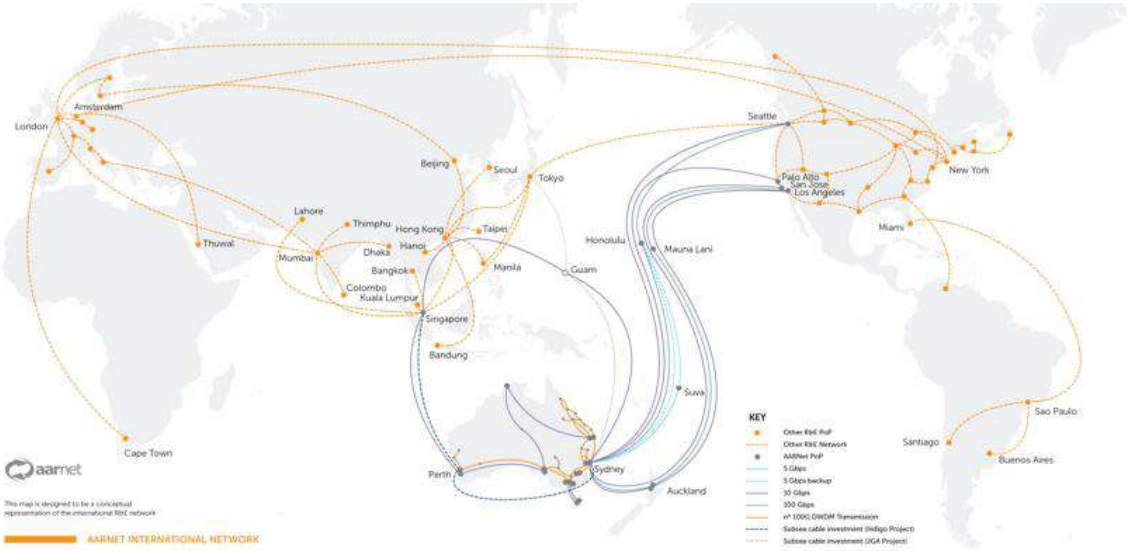


Fig. 5. Australia's Academic and Research Network (AARNet).

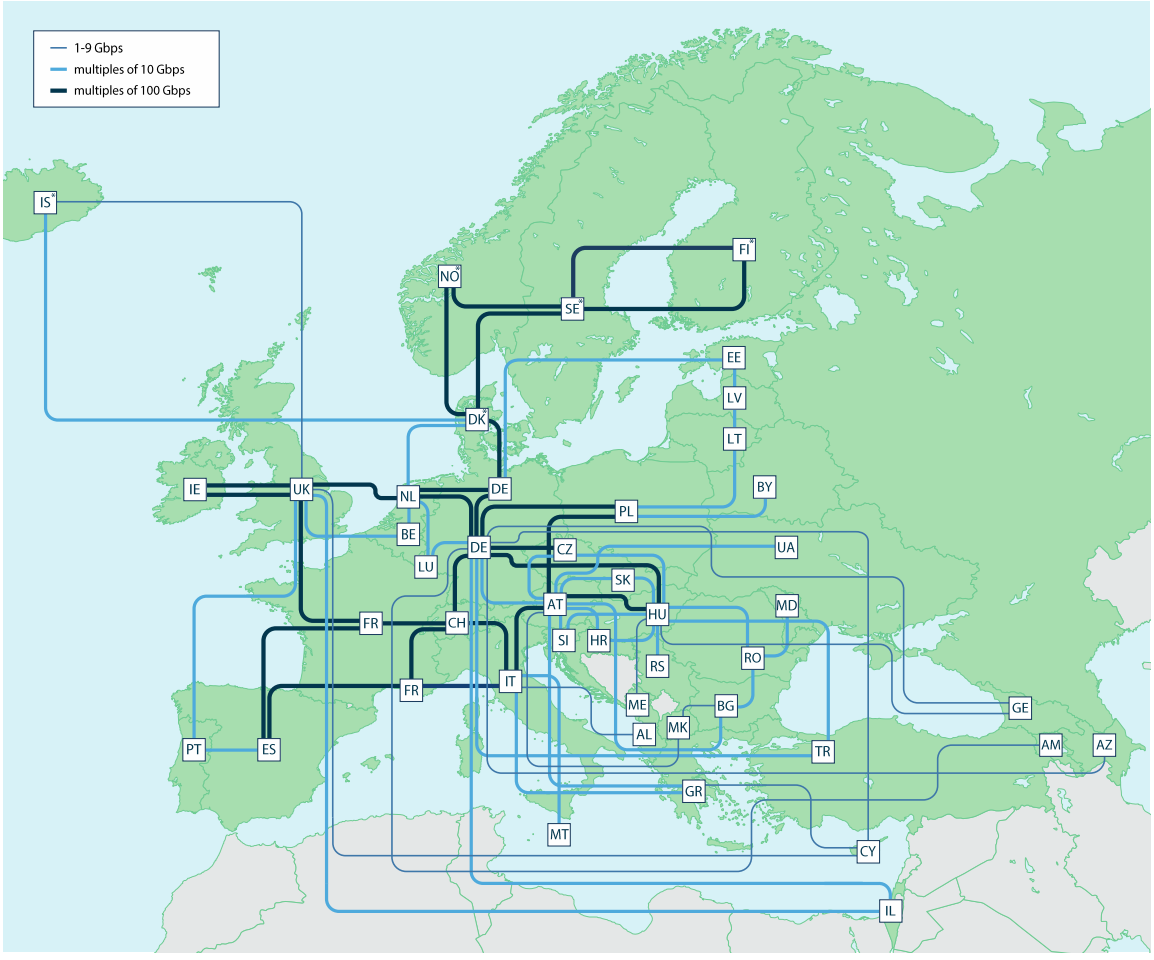


Fig. 6. European research and education network (GÉANT).

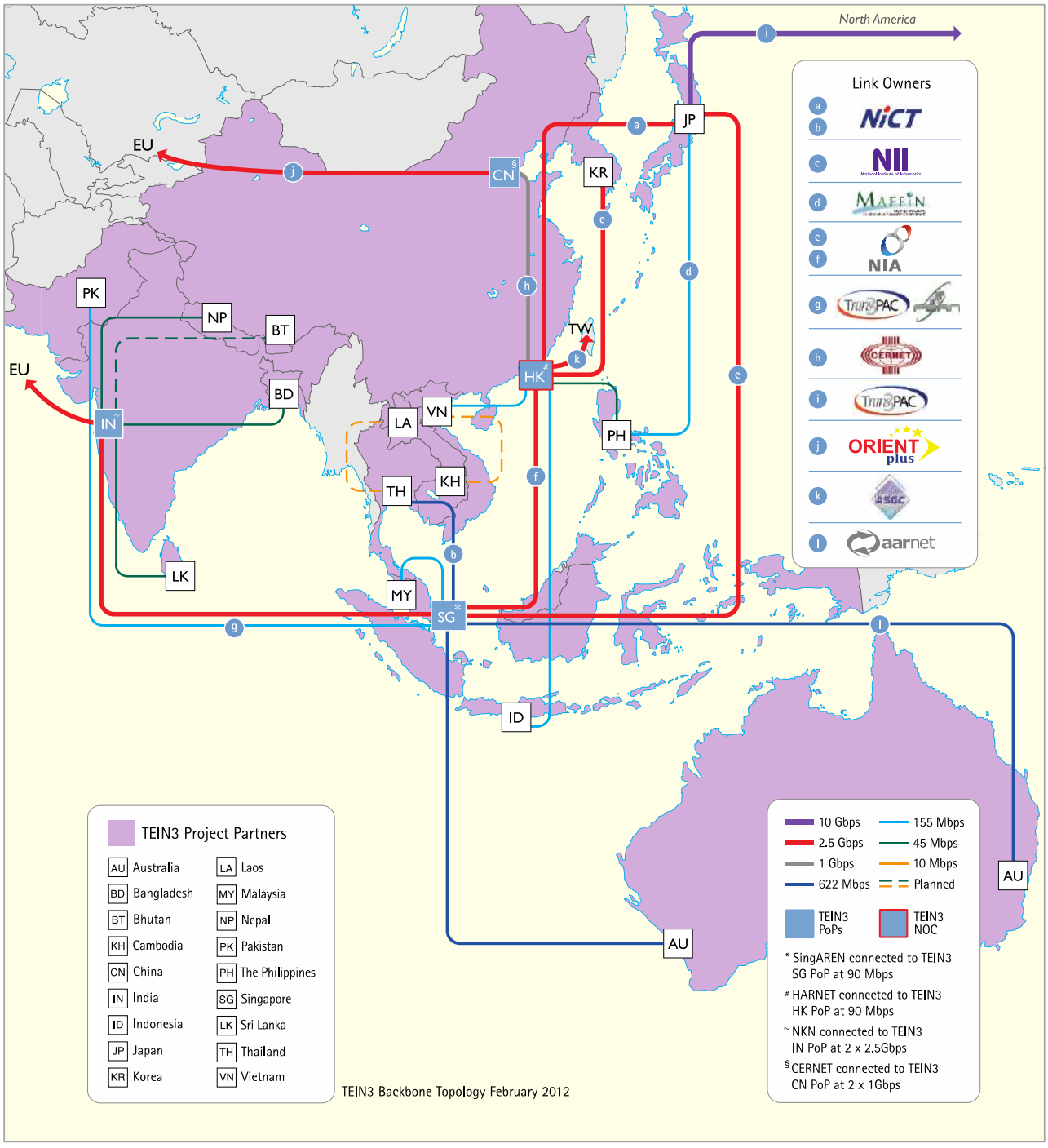


Fig. 7. Asia-Pacific research and education network (TEIN3).

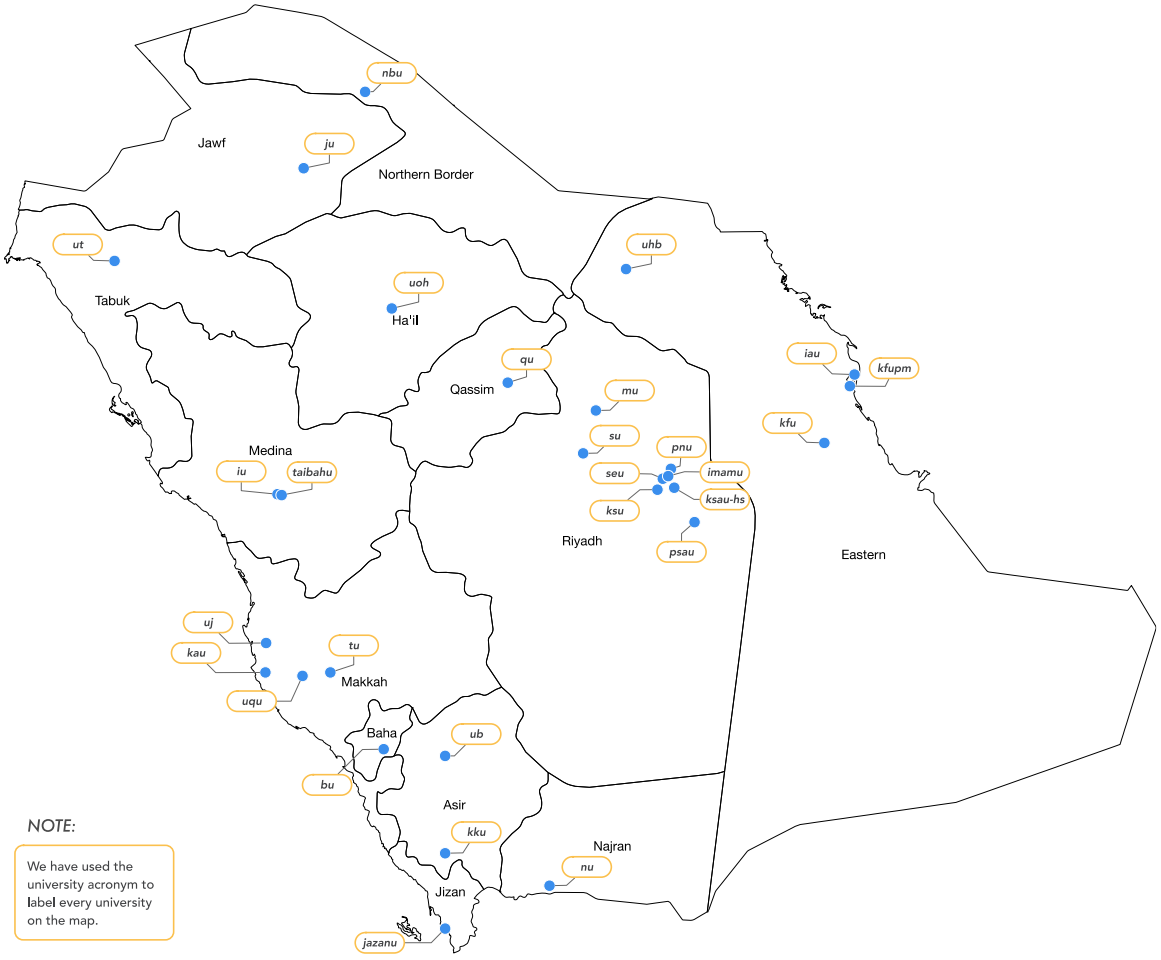


Fig. 8. Governmental universities in various provinces of Saudi Arabia (2020).

Table 2. List of Saudi Arabia governmental universities (2020).

no.	University Name	Acronym	Found.	Province	City	Latitude (° N)	Longitude (° E)	Total Users (stu.+fac	Budget 2015	Website
1	Umm Al Qura University	uqu	1949	Makkah	Makkah (Mecca)	21.3298411	39.9467004	131192	2,902,402,000	www.uqu.edu.sa
2	Islamic University of Madinah	iu	1961	Medina	Madinah (Medina)	24.4806619	39.5632639	19806	1,046,950,000	www.iu.edu.sa
3	Imam Muhammad bin Saud Islamic University	imamu	1974	Riyadh	Riyadh	24.8098187	46.6896421	142846	4,146,920,000	www.imamu.edu.sa
4	King Saud University	ksu	1957	Riyadh	Riyadh	24.7241106	46.6070068	90740	8,610,042,000	www.ksu.edu.sa
5	King AbdulAziz University	kau	1967	Makkah	Jeddah	21.4936618	39.2386967	198556	5,964,984,000	www.kau.edu.sa
6	King Fahd University of Petroleum and Minerals	kfupm	1963	Eastern	Dhahran	26.3062802	50.1410949	17953	1,357,566,000	www.kfupm.edu.sa
7	King Faisal University	kfu	1975	Eastern	Al Hofuf	25.3405395	49.5977223	175676	2,296,690,000	www.kfu.edu.sa
8	King Khalid University	kku	1998	Asir	Abha	18.2477312	42.5588225	77862	3,250,771,000	www.kku.edu.sa
9	Qassim University	qu	2004	Al Qassim	Al-Qassim	26.3488854	43.7646144	94604	2,604,821,000	www.qu.edu.sa

10	Taibah University	taibahu	2003	Medina	Medina	24.4860831	39.5399911	72990	2,354,690,000	www.taibahu.edu.sa
11	Taif University	tu	2004	Makkah	Taif	21.4327785	40.4897203	80922	2,102,730,000	www.tu.edu.sa
12	King Saud Bin AbdulAziz University for Health Sciences	ksau-hs	2005	Riyadh	Riyadh	24.7543489	46.8505533	16767	2,252,869,000	www.ksau-hs.edu.sa
13	Jazan University	jazanu	2005	Jizan	Jizan	16.9657537	42.539442	69681	1,747,985,000	www.jazanu.edu.sa
14	University of Hail	uoh	2006	Ha'il	Ha'il	27.6001847	41.6221257	46222	1,389,730,000	www.uoh.edu.sa
15	Al Jouf University	ju	2005	Al Jawf	Sakakah	29.7907536	40.0428053	36741	1,464,720,000	www.ju.edu.sa
16	University of Tabuk	ut	2006	Tabuk	Tabuk	28.3942656	36.4702737	44559	1,363,111,000	www.ut.edu.sa
17	Al Baha University	bu	2006	Al Baha	Al-Baha	19.9945413	41.481505	29648	1,017,751,000	www.bu.edu.sa
18	Najran University	nu	2006	Najran	Najran	17.633935	44.5300365	21525	1,224,141,000	www.nu.edu.sa
19	Princess Nourah Bint AbdulRahman University	pnu	2010	Riyadh	Riyadh	24.8466575	46.7233299	53035	2,685,780,000	www.pnu.edu.sa
20	Northern Border University	nbu	2007	Northern Border	Arar	30.9164946	41.0762408	24962	1,030,380,000	www.nbu.edu.sa
21	Shaqra University	su	2010	Riyadh	Shagra	25.1736465	45.1408992	39660	1,112,560,000	www.su.edu.sa
22	Prince Sattam Bin AbdulAziz University	psau	2008	Riyadh	Al Kharj	24.1531902	47.2696057	39262	1,340,170,000	www.psau.edu.sa
23	Imam AbdulRahman Bin Faisal University	iau	1975	Eastern	Dammam	26.3928049	50.1903986	51575	3,143,295,000	www.iau.edu.sa
24	Majmaah University	mu	2010	Riyadh	Majmaah	25.8683129	45.4187156	28004	1,038,970,000	www.mu.edu.sa
25	Saudi Electronic University	seu	2011	Riyadh	Riyadh	24.7940737	46.6767857	30779	385,910,000	www.seu.edu.sa
26	University of Jeddah	uj	2014	Makkah	Jeddah	21.8910178	39.2541407	21161	440,190,000	www.uj.edu.sa
27	University of Bisha	ub	2013	Asir	Bisha	20.0278032	42.6108894	21299	366,778,000	www.ub.edu.sa
28	University of Hafr Al Batin	uohb	2014	Eastern	Hafr al Batin	28.241555	45.9440088	23146	409,013,000	www.uohb.edu.sa

Table 3. Saudi Arabia NREN projects historical evolution.

Date	Network Name	Logo
2005[1]	Saudi NREN "مشاع" – مشروع الشبكة الوطنية الأكاديمية	NA
2009[2]	Saudi Academic Research and Educational Network (SAREN)	
2011[3]	Saudi Academic Research and Innovation Network (SARInet)	NA

[1] Dr. Mishaal Abdullah Al-Kadhi resume, then Director of the Internet Services Unit at KACST, stated that he initiated the Saudi NREN project between 1426H (2005G) and 1427H (2006G). Also, he was a consultant for the Saudi NREN – SAREN on 1429H – 1430H (2008G-2009G).

[2] Dr. Hesham bin Abbas, then Director of the Internet Services Unit at KACST, Presentation on "The 4th Arab Conference for Industrial Information, Networks and the Accompanying Exhibition", The Role of the academic Networks in supporting industry in Saudi Arabia, 20 Dec. 2009. Also, another presentation on "Saudi Arabian High Performance Computing: Past, Present and Future Symposium", Developing a National Research and Educational Network in Saudi Arabia, 6 Dec. 2011.

[3] http://asrenorg.net/?q=content/saudi-arabia-0, accessed: 18 Sep. 2020.

21 Dec. 2017[4]	Saudi Research & Innovation Network (MAEEN) الشبكة السعودية للبحث والابتكار (معين)	

[4] https://www.maeen.sa/en/maeen-launch-ceremony/, accessed: 18 Sep. 2020.

6. Methods

In this section we focus on our way for collecting the data required for further investigation about the current status of the NREN in the KSA. It is important to note that we have used the official websites, some online tools and some networking techniques, such as using the Domain Name System (DNS) and network tracing, to consolidate the needed information. The information collection was performed around and during the month of September 2020. We collected data for a period almost extending for one year between November 2019 and November 2020 (see Appendix A). A sample of the collected data could be found in Appendix B. Also, Appendix C contains the data extracted from the TERENA Compendium report[27]. The report gives very detailed statistics about GÉANT partner countries.

Before we dive into the technicality and methods used for the tracing, it is important to highlight some basic information that is necessary to understand the Internet Registry System (IRS). The Internet number resources are distributed globally according to a hierarchical registry system that has evolved over the past two decades. The Internet Assigned Numbers Authority (IANA) distributed the resources, including IP address space and Autonomous System Number (ASN), on five Regional Internet Registries (RIRs) (see Fig. 9)[28] and then onto their Local Internet Registers (LIRs). Figure 10 shows the hierarchical structure of the resource allocation scheme. The *End User* is an entity that uses the IP address space for its network only and does not provide IP/ASN services to customers.

From the information in the previous section, we know that currently there are two Saudi entities having connections with global NRENs, namely KAUST and KACST-ISU. So, we need to find out their IP/ASN. Since KSA is part of the RIPE NCC (Réseaux IP Européens Network Coordination Centre) area, we can find the information about IP and ASN from the RIPE NCC database[29].

Information about the Border Gateway Protocol (BGP) peering, as a form of ASN, can be deduced from RIPE NCC website[29]. The tool is called *BGPlay* and it can present progression of the BGP routes and peering changes over a period of time. The tool presents the information collected from various probes. There are other websites that can extract useful information about the targeted organization such as *Hurricane Electric*[30] and *IPinfo*[31].

Always NRENs are keen to provide tools to share their networks status for the public. The network traffic utilization for any link can be measured from either ends of the link. The outgoing packet from the first end (egress) is seen as the incoming packet from the other end (ingress) and vice versa. In our study, the data were collected from the global end because there is no public data visibility for the local side. The network GÉANT offers valuable tools that are available for the global users and it can be found in that network tools portal[32]. Also, NRDUnet has its global tools that gives beneficial visibility[33]. The network Internet2 has a global Network Operation Center (NOC) that can be easily accessed[34].

7. Results

In this section we present the results gathered from various monitoring tools stated in the previous section. Table 4 shows the organizations and the corresponding ASN for each of them. Figure 11 shows a specific network advertisement for KAUST NREN peering, while Fig. 12 presents the network advertisement for KAUST normal Internet peering. Figures 13 and 14 represent KACST-ISU BGP network advertisement for the

Islamic University and Taif University, respectively.

For the NREN links data utilization during the month of September (2 hours average), Fig. 15 represents the traffic exchange between GÉANT and KAUST, KACST-ISU (Saudi Arabia), SINET (Japan), AARNET (Australia), INTERNET2 (United States) in Mbps. While in Fig. 16, we have removed Internet2 and SINET from Fig. 15 and kept AARNET in the same graph because Australia's population is around 25 million, which is comparable to (8 million less than) the KSA population. Figure 17 shows the total traffic for the global NRENs combined towards KAUST and KACST-ISU. It is important to note that KACST-ISU has around 50 customers including 18 of the governmental universities. The global NREN traffic exchange with KACST-ISU includes all its customers. Figure 18 represents a weekly traffic (30 minutes average) from KSA parties towards GÉANT. To have a better view, the figure is redrawn as two separate figures, namely Fig. 19 and Fig. 20, which represent KAUST traffic and KACST-ISU traffic, respectively.

Services provided to governmental universities are presented in Table 5. The services are organized based on the service provider for every university. The services provided by listed service providers could be, the Internet, cloud services, Denial of Service (DoS) protection, web hosting and DNS colocation. We represent the service availability with 1 and its unavailability with 0. We also listed the IP address assignment status.

8. Discussions

In this section, we discuss how we analyze the various universities' situations. Also, we represent the various results from Table 5 in Fig. 21, 22 and 23. We give some basic descriptive statistical analysis of the data extracted from Fig. 15 and 17 in Tables 6 and 7.

From the BGP advertisements in Fig. 11-14, we can see that KACST-ISU is advertising its customer's networks to both the Internet and the NREN peers. This is going to mix both kinds of traffic in the same link on its customer facing link, and this makes the distinction from customer's side very difficult. On the other hand, we can see that KAUST has a better strategy by splitting the network advertisements and having a network that is dedicated for NREN peering.

In terms of SP governmental universities share, KACST-ISU has the largest share with 37% followed by 27% for STC and 20% for Mobily. By contrast with the early situation of the Internet in Saudi Arabia, KACST-ISU was the dominant SP for almost all the governmental universities. This means that the diversity of servers is notably larger, and hence better, nowadays.

From Fig. 23 we can see that there are 8 out of the 28 universities (i.e., less than 29%), which have IP addresses that are independent of a specific service provider. The remaining 20 universities have IP ranges which are dependent on a specific service provider. The IP address dependency is making the technical decision of changing a service provider more difficult. Moreover, publishing services on multiple service providers requires dependent IP addresses from every service provider. Therefore, some universities have selected to publish some of its services on local or global cloud providers. Prince Sattam Bin AbdulAziz University (PSAU) has two IP address types, one is provider-independent (PI) and the other one is provider-dependent (PD).

In Fig. 24 we can observe that there are approximately 53% out of GÉANT partners with less than 20% client's affordability ratio.

Moreover, in Bulgaria, Greece, Lithuania, Montenegro, Romania, Slovenia, Spain and Turkey the clients are paying 0%, i.e., it is either fully supported by the national government or funded by the European Union. While 31% of the members of GEANT pay between 21% to 80%, only 16% of the clients pay 81% to 100% of the charges. The only two countries with 100% client charge are Austria and Denmark.

In Tables 6 to 11 we present some results of statistical analysis extracted from the collected data[35]. Following are some of the useful statistical measures for assessing the central tendency, spread and higher measures of variability[36]:

- **Mean** – This is the arithmetic mean (average, expected value or expectation) of all the data observed It is the most widely used measure of the central tendency of the data. Other prominent measures of the central tendency include the median and the mode. The mean is obtained as the sum of all numbers in the observed data set, divided by the set cardinality (number of set elements). The median is the middle value when the data set is arranged in a non-increasing or a non-decreasing order. The mode is the number that occurs most frequently in the data set. Notable disadvantages of the mean are (a) its unwarranted sensitivity to outliers constituting extremely large or extremely small values, and (b). That it might not belong to the original data set.
- **Std. Dev.** – This is the standard deviation (square root of the variance or the second central moment) of the data set. It gives information regarding the spread of the distribution of the data set.
- **Skewness** – Skewness is the third scaled central moment, and it measures the degree and direction of asymmetry (lack of symmetry). A symmetric distribution such as a normal distribution has a skewness of 0, while a distribution that is skewed to the left, e.g., when the mean is less than the median, has a negative skewness.
- **Kurtosis** – Kurtosis is the fourth scaled central moment, and it is a measure of the heaviness of the tails of a distribution compared to those of the normal distribution. A normal distribution has a kurtosis of 3. Heavy tailed distributions have kurtosis values greater than 3 and light tailed distributions have kurtosis values less than 3.
- **50%** score – This is the 50^{th} percentile, also known as the median. If the values of the variable are ordered from lowest to highest, the median would be the value exactly in the middle, with half of the values being below the median, and half being above it. This is a good measure of central tendency if the variable has outliers.
- **75%** score– This is the 75^{th} percentile, also known as the third quartile.
- **95%** score– This is the 95^{th} percentile, and is useful for network capacity planning.
- On the month of September 2020, the extracted descriptive statistics for the traffic between GÉANT and its peers is shown in Table 6. Even though there are around 51 customers[26] including 18 governmental universities having connections with KACST-ISU, there is a very minimal traffic in average to GÉANT (almost zero). However, we can see that there is an 18 Mbps on average between KAUST and GÉANT. From Fig. 25, we can see that the majority of

KSA traffic share with global NRENs is exchanged with KAUST, constituting more than 95% of the total traffic throughout the year.

- Figure 26 demonstrates that, on average, most of the data traffic flow is from global NRENs to KSA. There is an exception for KAUST maximum traffic in Fig. 26 (b), where we can see that the maximum outgoing traffic is higher than the maximum ingoing traffic. This is due to the fact that sometimes there is a larger upload burst towards global NRENs. The outgoing traffic is important to measure the level of contribution from local research and education towards global NRENs.

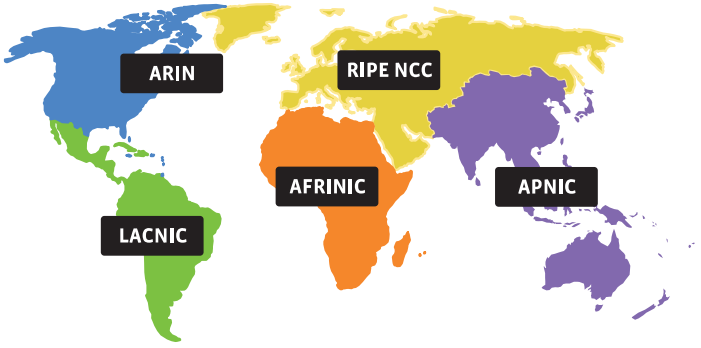


Fig. 9. The five Regional Internet Registries (RIRs).
Source: www.iana.org

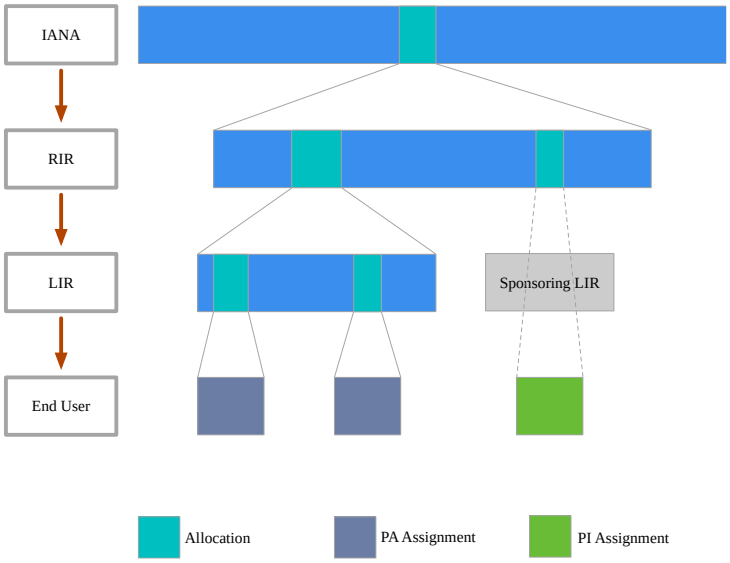


Fig. 10. Resource allocation hierarchical structure.

Table 4. BGP ASN for related organizations.

Organization	BGP ASN
GÉANT	20965
Internet2	11537

KACST-ISU	8895
KAUST	50999
NORDUnet	2603

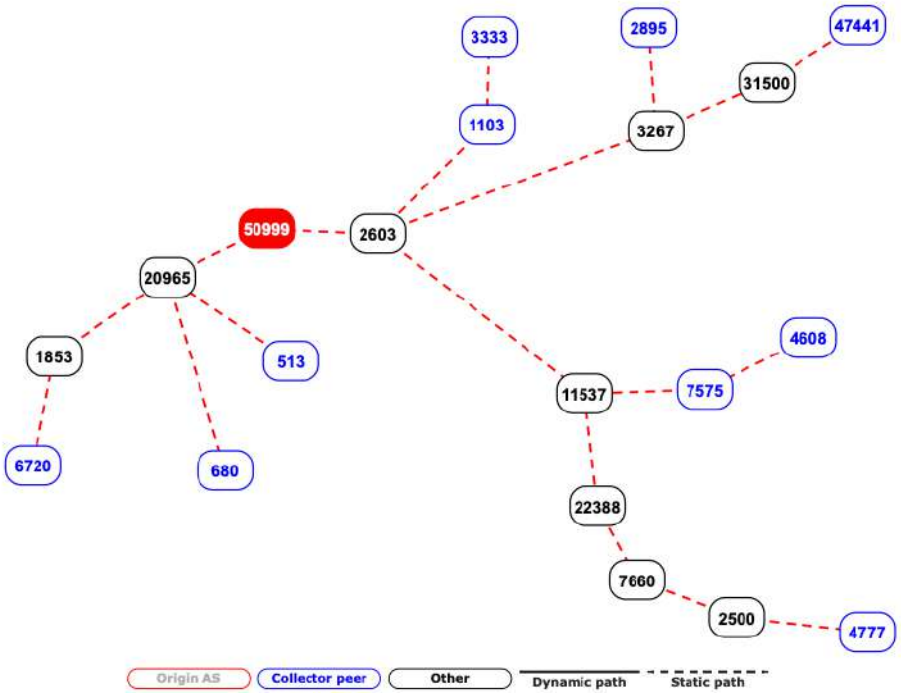


Fig. 11. KAUST BGP IPv4 NREN visibility for its network (109.171.131.0/24).

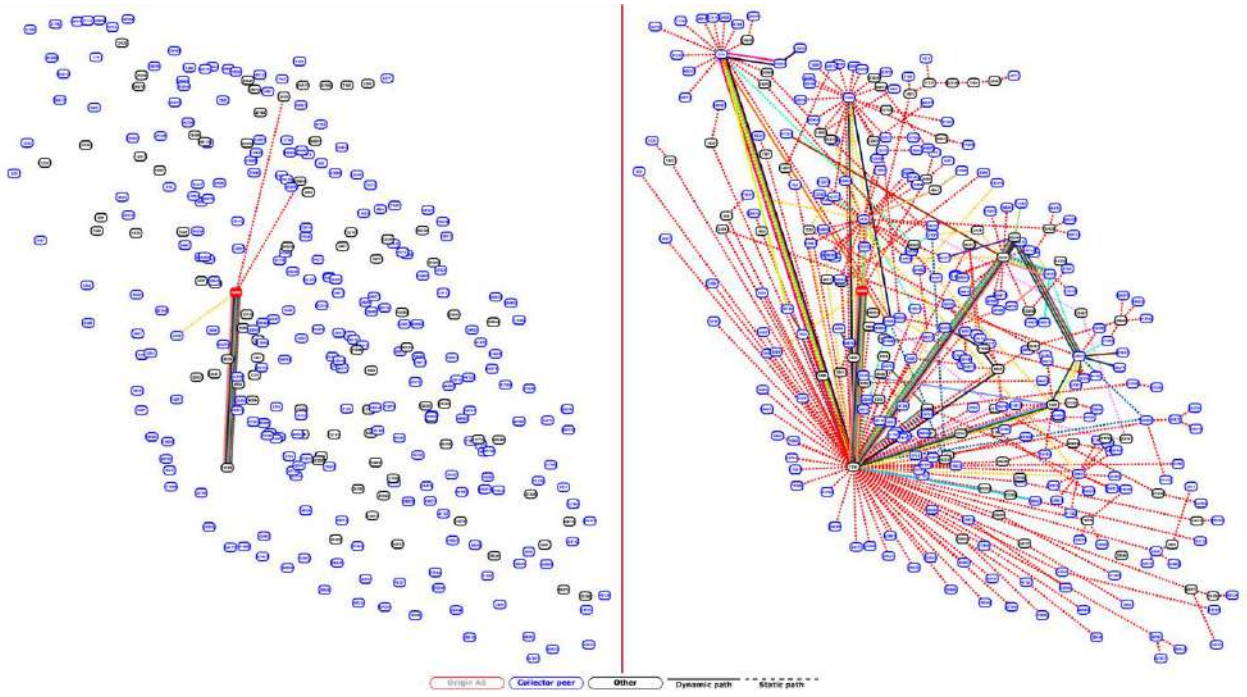


Fig. 12. KAUST BGP IPv4 visibility for its network (109.171.137.0/24) (left: 1 hop, right: up to 8 hops).

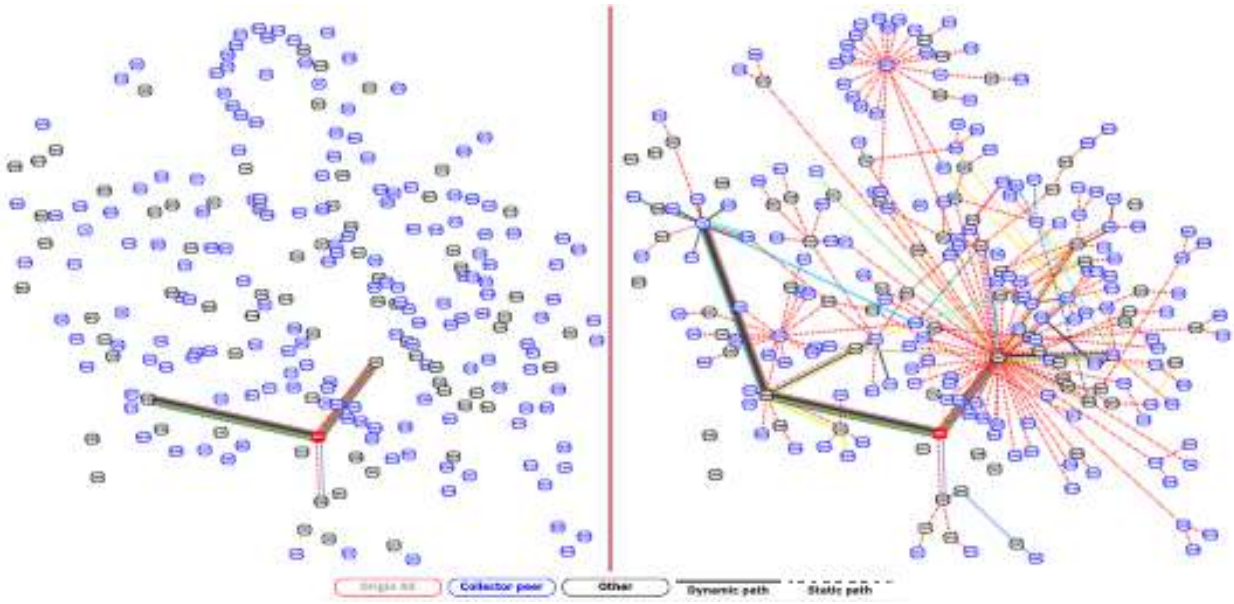


Fig. 13. KACST-ISU BGP Islamic university route visibility (left: 1 hop, right: up to 7 hops).

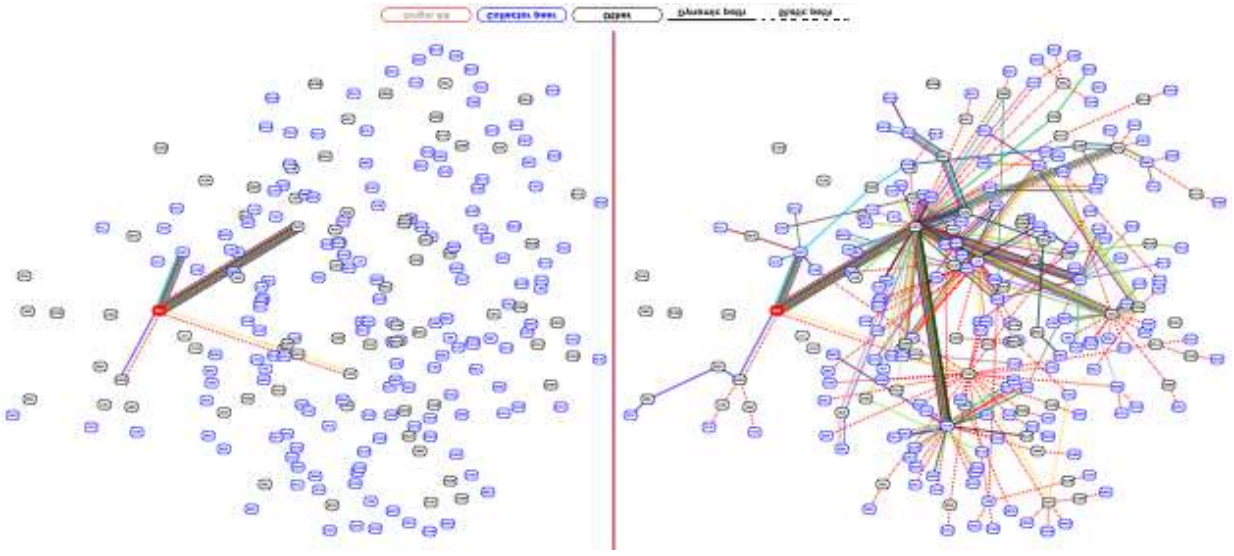


Fig. 14. KACST-ISU BGP Taif university route visibility (left: 1 hop, right: up to 7 hops).

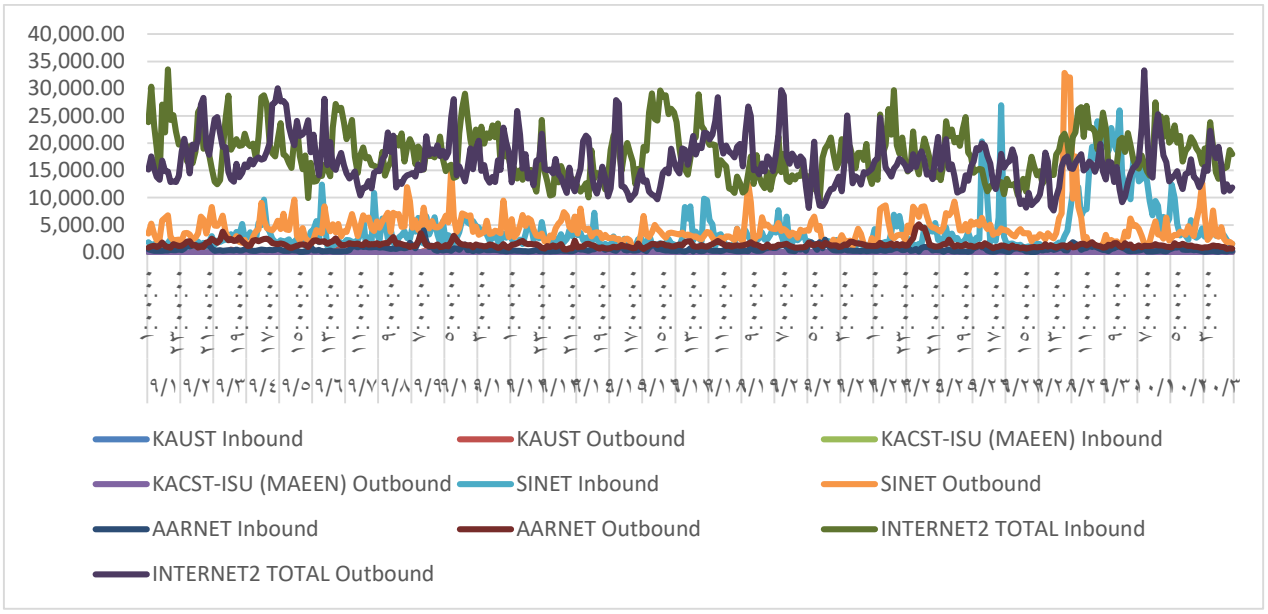


Fig. 15. Data Traffic exchange in the month of September, 2020 between GÉANT and KAUST, KACST-ISU (Saudi Arabia), SINET (Japan), AARNET (Australia), INTERNET2 (United States) in Mbps.

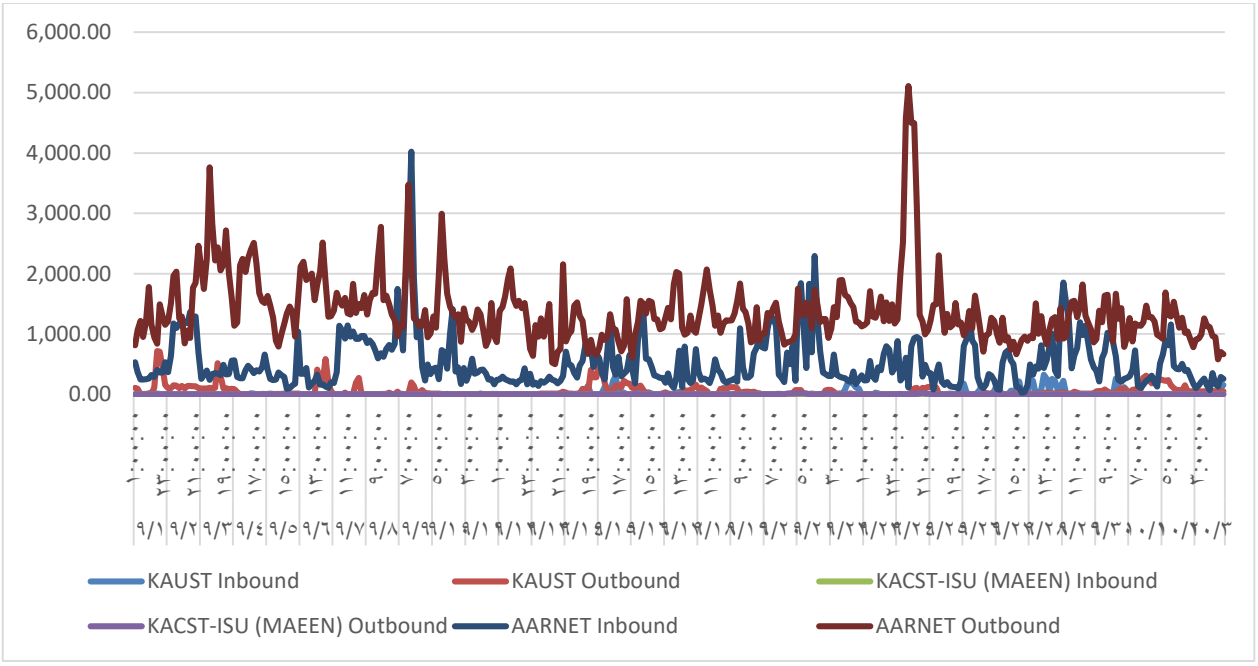


Fig. 16. Data traffic exchange in the month of September, 2020 between GÉANT and KAUST, KACST-ISU (Saudi Arabia), AARNET (Australia) in Mbps.

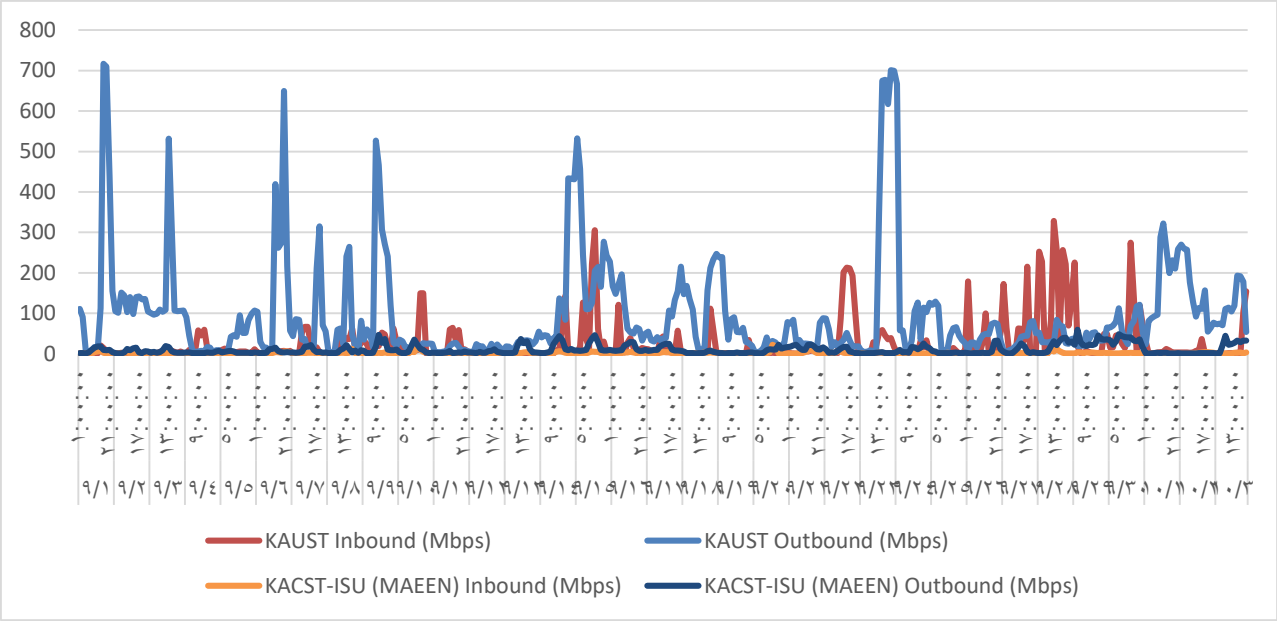


Fig. 17. Total traffic for (GÉANT + NORDUnet) towards KAUST, and (GÉANT + Internet2) towards KACST-ISU during the month of September, 2020.

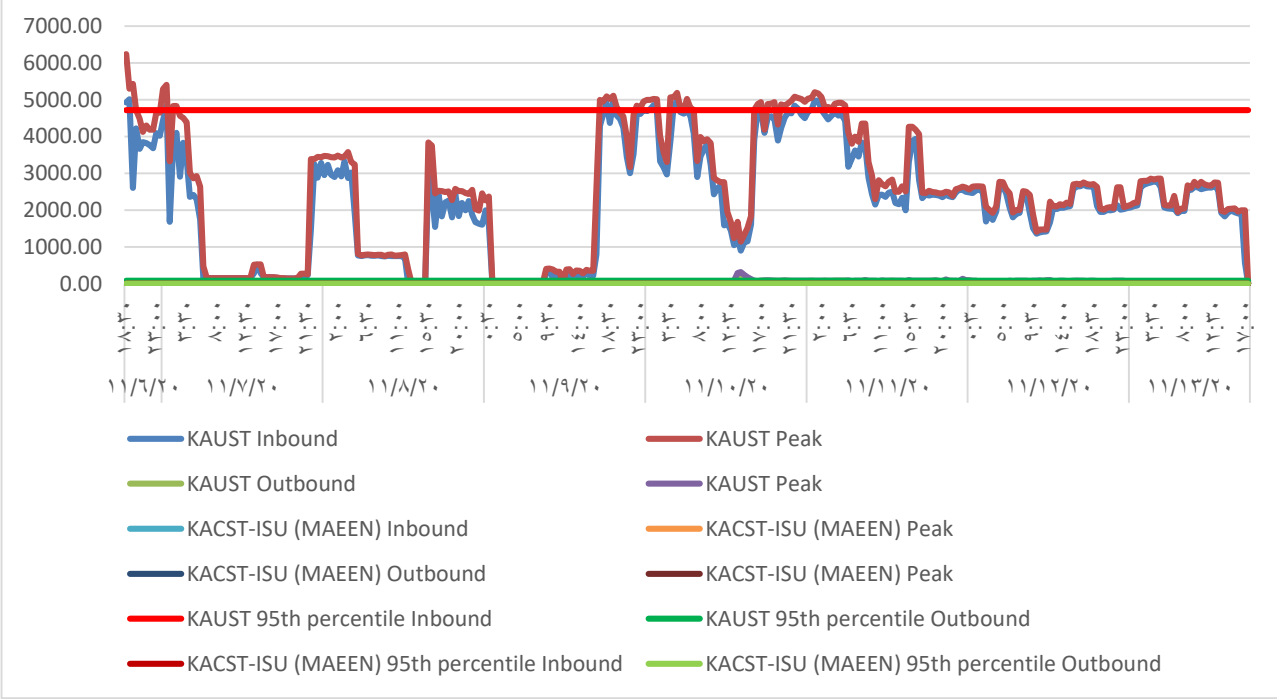


Fig. 18. Data traffic exchange between GÉANT and KAUST, KACST-ISU (MAEEN) for one week (06 - 13 November, 2020) in Mbps.

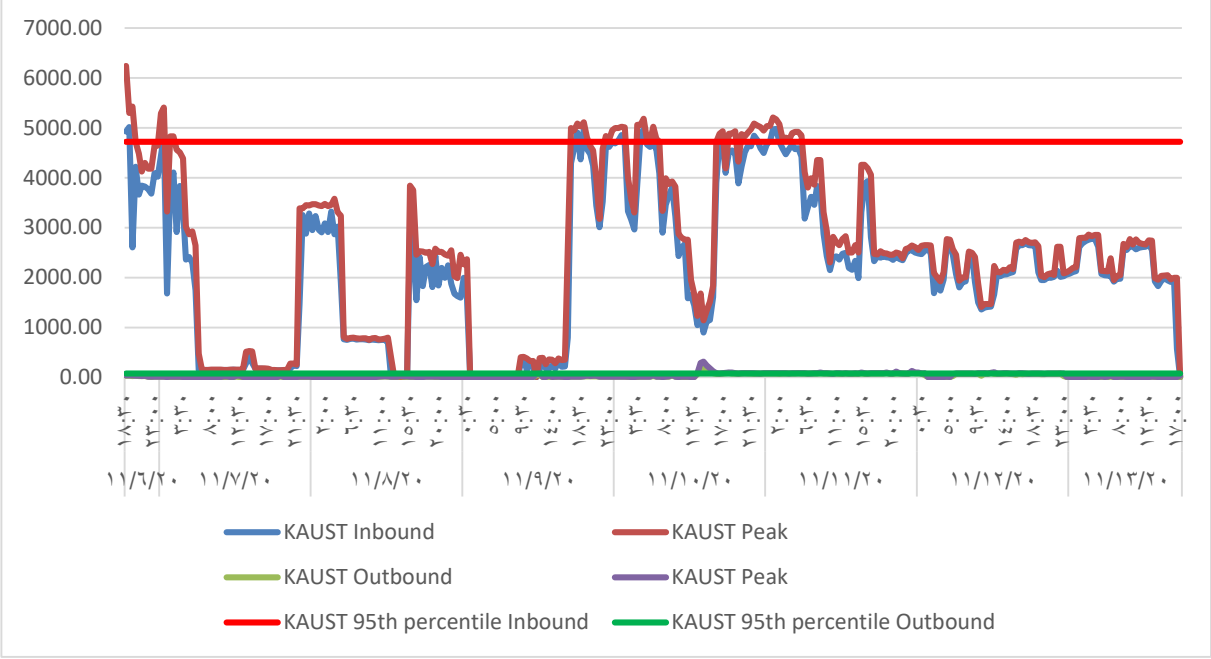


Fig. 19. Data traffic exchange between GÉANT and KAUST for one week (06 - 13 November, 2020) in Mbps.

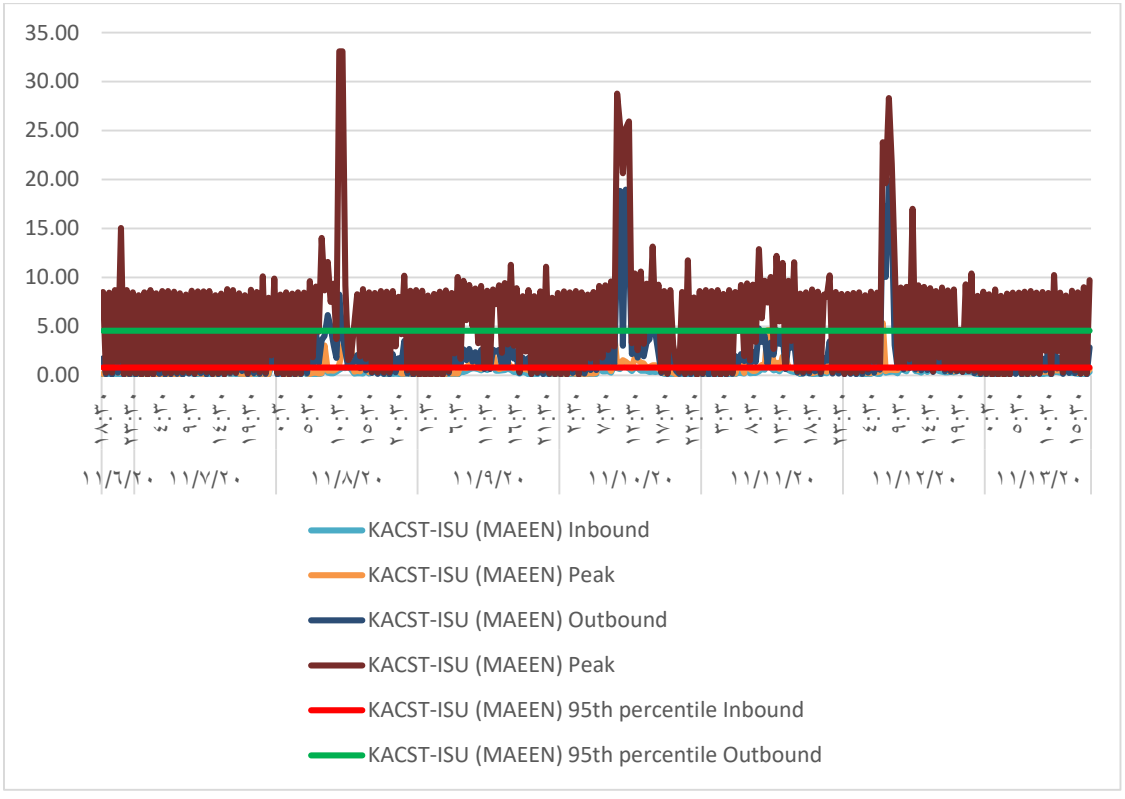


Fig. 20. Data traffic exchange between GÉANT and KACST-ISU (MAEEN) for one week (06 - 13 November, 2020) in Mbps.

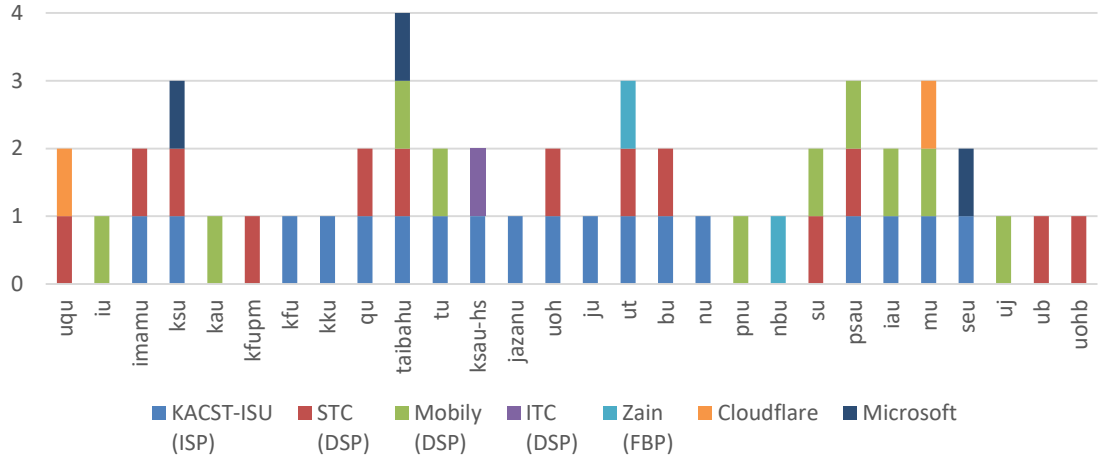


Fig. 21. Governmental universities subscriptions with different service providers.

Table 5. Governmental universities service provider status.

no.	Acronym	IPv4 status	IPv6 Services	org-type	University ASN	Service Provider[5]						
						KACST-ISU	STC	Mobily	ITC	Zain	Cloudflare	Microsoft
1	uqu	PA	NA	OTHER	_	0	1	0	0	0	1	0
2	iu	PA	NA	OTHER	_	0	0	1	0	0	0	0
3	imamu	PI	NA	OTHER	AS62452	1	1	0	0	0	0	0
4	ksu	PA	NA	LIR	AS50517	1	1	0	0	0	0	1
5	kau	PI	NA	OTHER	AS15505	0	0	1	0	0	0	0
6	kfupm	LEGACY	NA	OTHER	_	0	1	0	0	0	0	0
7	kfu	PA	NA	OTHER	_	1	0	0	0	0	0	0
8	kku	PA	NA	OTHER	_	1	0	0	0	0	0	0
9	qu	PA	NA	OTHER	_	1	1	0	0	0	0	0
10	taibahu	PA	NA	OTHER	_	1	1	1	0	0	0	1
11	tu	PA	NA	OTHER	_	1	0	1	0	0	0	0
12	ksau-hs	PA	NA	LIR	AS209464	1	0	0	1	0	0	0
13	jazanu	PA	NA	OTHER	_	1	0	0	0	0	0	0
14	uoh	PA	NA	OTHER	_	1	1	0	0	0	0	0
15	ju	PA	NA	OTHER	_	1	0	0	0	0	0	0
16	ut	PA	NA	OTHER	_	1	1	0	0	1	0	0
17	bu	PA	NA	OTHER	_	1	1	0	0	0	0	0
18	nu	PA	NA	OTHER	_	1	0	0	0	0	0	0
19	pnu	PA	NA	OTHER	_	0	0	1	0	0	0	0
20	nbu	PA	NA	LIR	AS210248	0	0	0	0	1	0	0
21	su	PA	NA	OTHER	_	0	1	1	0	0	0	0
22	psau	PI, PA	NA	OTHER	AS60161	1	1	1	0	0	0	0
23	iau	PI	NA	OTHER	AS56714	1	0	1	0	0	0	0
24	mu	PA	NA	OTHER	_	1	0	1	0	0	1	0
25	seu	PA	NA	OTHER	_	1	0	0	0	0	0	1
26	uj	PA	NA	OTHER	_	0	0	1	0	0	0	0
27	ub	PA	NA	OTHER	_	0	1	0	0	0	0	0
28	uohb	PA	NA	OTHER	_	0	1	0	0	0	0	0
	TOTAL	¬PA = 5	0	LIR = 3	7	18	13	10	1	2	2	3

[5] A service provider is assigned one of two values; 0 means there is no service while 1 means that there is a service from that service provider.

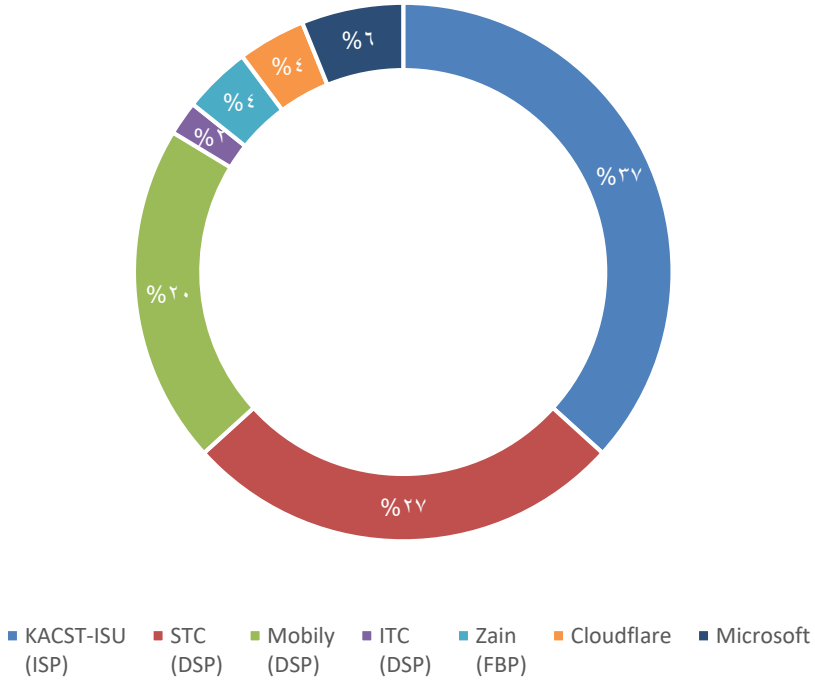


Fig. 22. Service providers share by the number of governmental universities.

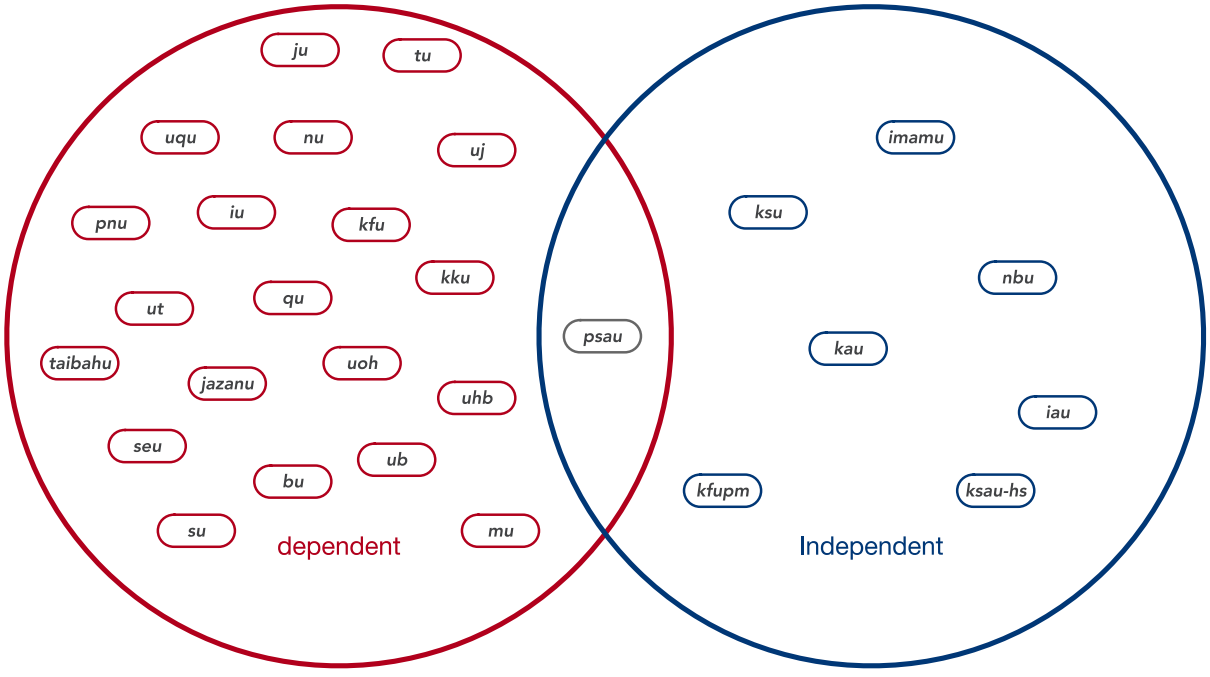


Fig. 23. Governmental universities IP allocation status.

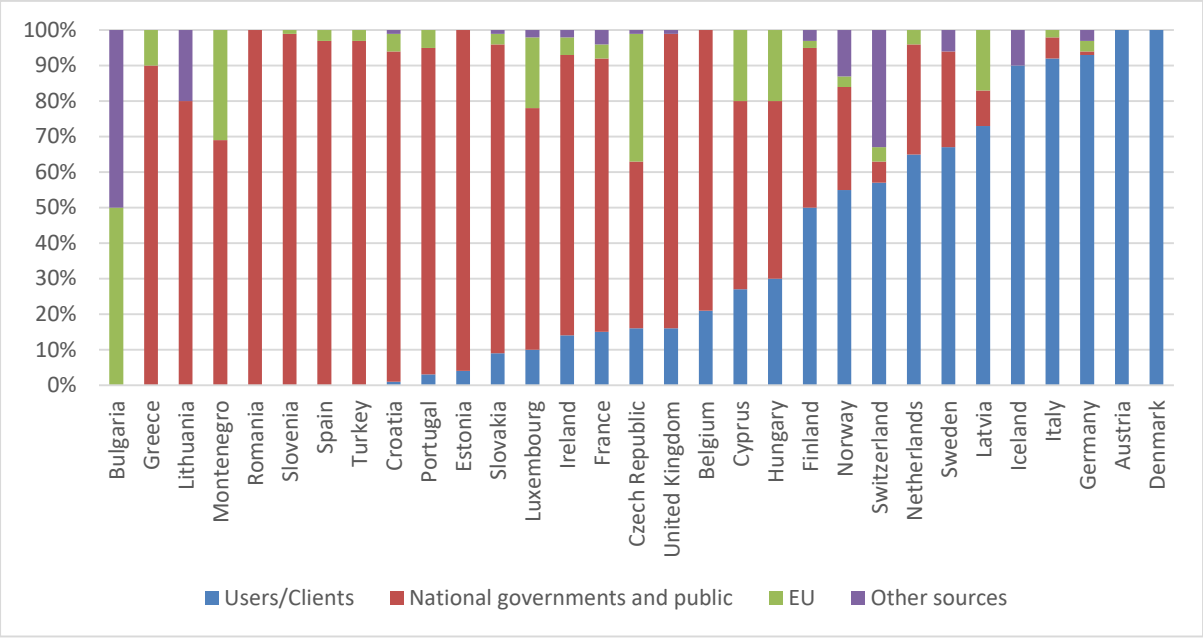


Fig. 24. Income sources for some GÉANT partner countries[27].

Table 6. Descriptive statistics for data traffic exchange in the month of September 2020 between GÉANT and INTERNET2, SINET, AARNET, KAUST and KACST-ISU.

	Mean (Mbps)		Std. Dev. (Mbps)		Minimum (Mbps)		Maximum (Mbps)	
	In	Out	In	Out	In	Out	In	Out
INTERNET2	18,011.46	16,413.64	4,464.55	4,324.39	9,534.89	7,670.22	33,566.60	33,376.95
SINET	3,984.61	4,394.60	4,309.22	3,272.01	770.57	581.74	26,988.98	32,901.76
AARNET	524.43	1,378.30	426.05	567.23	29.73	502.85	4,021.97	5,107.01
KAUST	18.05	56.19	50.46	96.13	0.01	0.16	327.14	716.67
KACST-ISU	0.42	2.08	0.69	3.05	0.03	0.48	4.81	25.15

Table 7. Descriptive statistics for total data traffic exchange in the month of September 2020 from global NRENs towards KAUST and KACST-ISU.

	Mean (Mbps)		Std. Dev. (Mbps)		Minimum (Mbps)		Maximum (Mbps)		Median (Mbps)	
	In	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
KAUST	24.84	96.06	52.46	129.89	0.02	1.41	328.29	716.67	3.78	50.79
KACST-ISU	1.63	9.98	2.27	11.31	0.04	0.84	21.97	59.43	0.94	4.89

Table 8. Descriptive statistics for total data traffic exchange in the month of September 2020 from global NRENs towards KAUST and KACST-ISU.

	Skewness		kurtosis		95th Percentile		75th Percentile		50th Percentile	
	In	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
KAUST	3.27	2.80	11.17	8.74	145.33	329.26	18.54	110.38	3.78	50.79
KACST-ISU	4.70	1.56	29.64	1.84	5.15	34.57	1.79	14.82	0.94	4.89

Table 9. Average and maximum traffic between global NRENs and KAUST for one year (global NRENs perspective).

	GÉANT				NORDUnet			
	Mean (Mbps)		Maximum (Mbps)		Mean (Mbps)		Maximum (Mbps)	
	In	Out	In	Out	In	Out	In	Out
KAUST	115.29	111.82	4454.4	2478.08	6.86	121.2	109.58	920.3

Table 10. Average and maximum traffic between global NRENs and KACST-ISU for one year (global NRENs perspective).

	GÉANT				Internet2			
	Mean (Mbps)		Maximum (Mbps)		Mean (Mbps)		Maximum (Mbps)	
	In	Out	In	Out	In	Out	In	Out
KACST-ISU	0.448	1.41	9.51	14.48	1.6	8.9	6.4	121.3

Table 11. Average and maximum traffic between KAUST, KACST-ISU and global NRENs for one year (local perspective).

	Mean (Mbps)		Maximum (Mbps)	
	Out	In	Out	In
KAUST	122.15	233.02	4563.98	3398.38
KACST-ISU	2.048	10.31	15.91	135.78
TOTAL	124.198	243.33	4579.89	3534.16

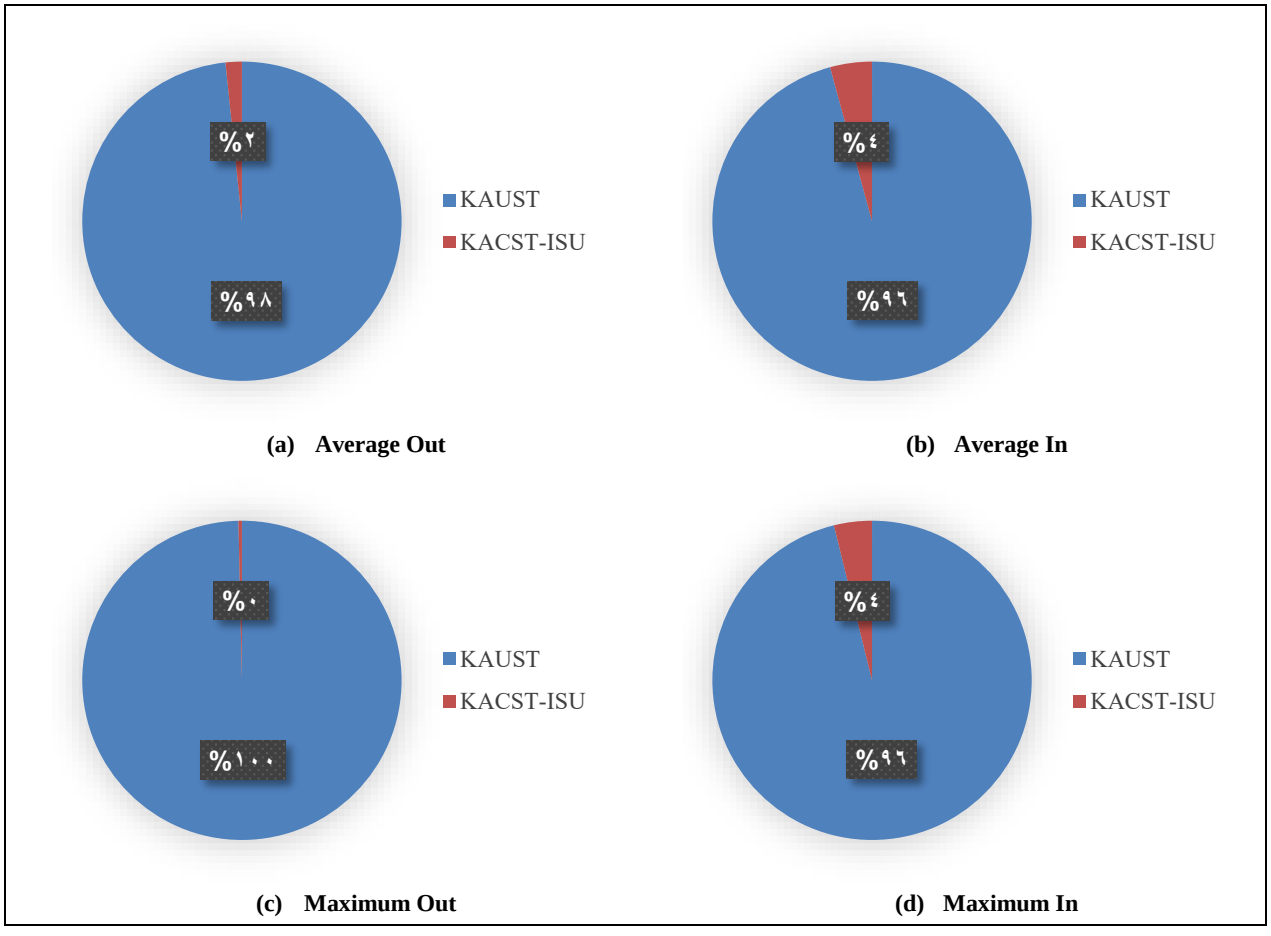


Fig. 25. The KSA traffic share towards global NRENs.

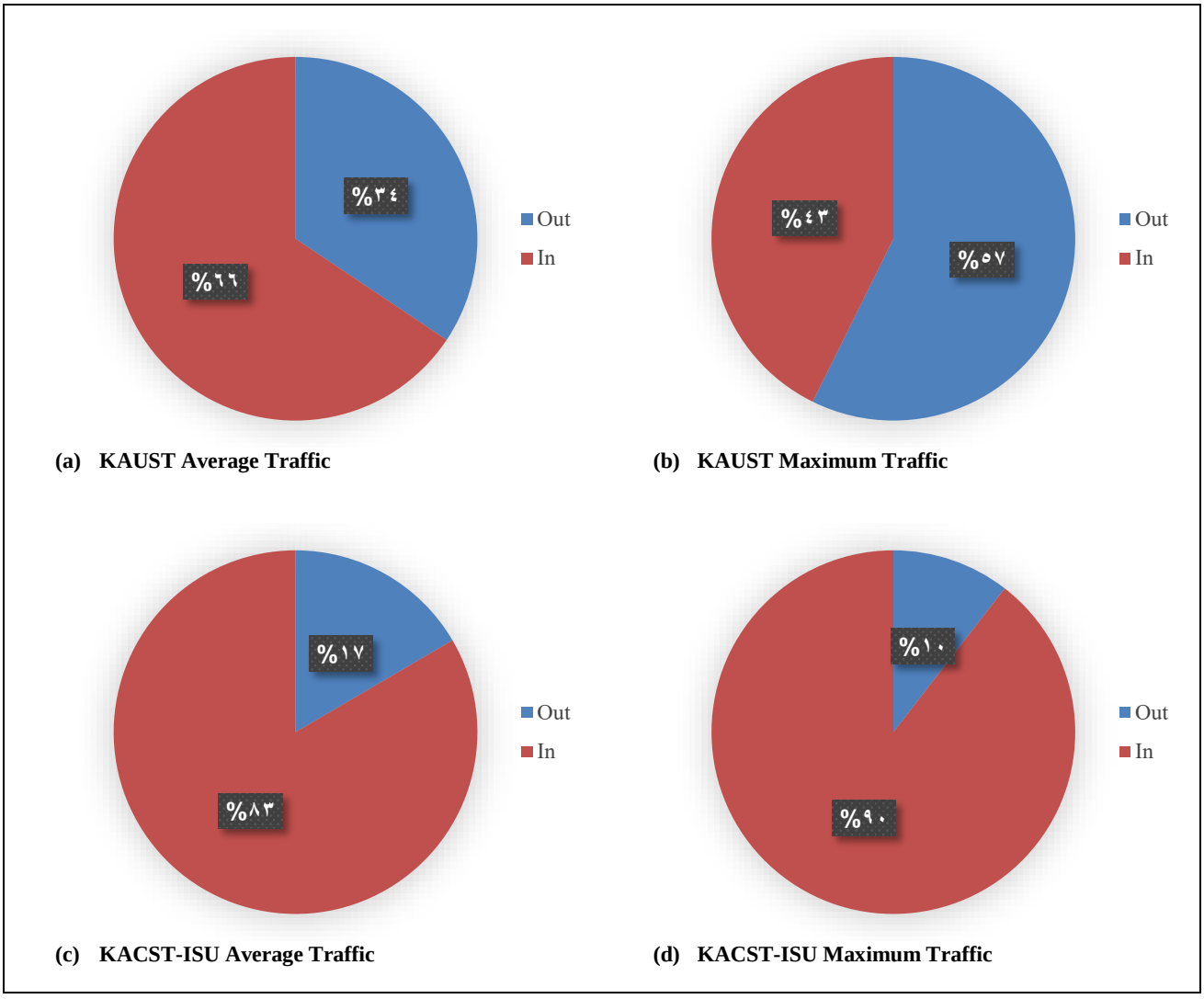


Fig. 26. Traffic share towards global NRENs for different KSA organizations based on direction.

5. Conclusions

The success of a NREN is highly dependent on the research community utilizing it. If there is no large take-up of its services, a NREN will most probably be doomed to failure, or at least fall short of achieving its intended goals. Comparing the contribution to global NRENs during the past year, we observe that KAUST has 98% of the average traffic going out of (and 96% of the average traffic coming into) Saudi Arabia, while KACST-ISU accounts for 2% and 4% of the outgoing traffic and incoming traffic, respectively.

Hypothetically, NRENs secure attractive environments for the research community to collaborate, contribute and progress. That requires greater efforts to encourage and engage the research community with local and global research groups. Moreover, the financial model of the NREN should be convincing for its members. There are various funding models for NRENs. Currently KACST-ISU is a full profit organization, which means that its customers are

paying 100% of the link costs, which is normally higher than the direct DSP link cost. By contrast, 53% of the GÉANT customers pay less than 20% for the NREN services. Generally, most of GÉANT countries use a combination of government subvention, membership fees, and user service fees[37]. For example, JANET (United Kingdom NREN) requires its members to pay 16% of the cost for the NREN, while in Ireland, the customers' share of the cost is 15%. If connected institutions are charged for the connectivity and services provided by NRENs, this should be done in such a way that it is not a disincentive for innovation .

The reliability of the current NREN design in the KSA needs to be further analyzed since there are two POPs only. A prominent goal is to establish a better way of managing this NREN, as a national project of crucial importance. We hope that the research and education community can offer more contributions towards this shared goal. A more efficient involvement of the research community will enhance the quality of research and will add extra income from research contributions.

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Appendix A

One Year Traffic Figures for the Period from 2019.11.03 to 2020.11.03

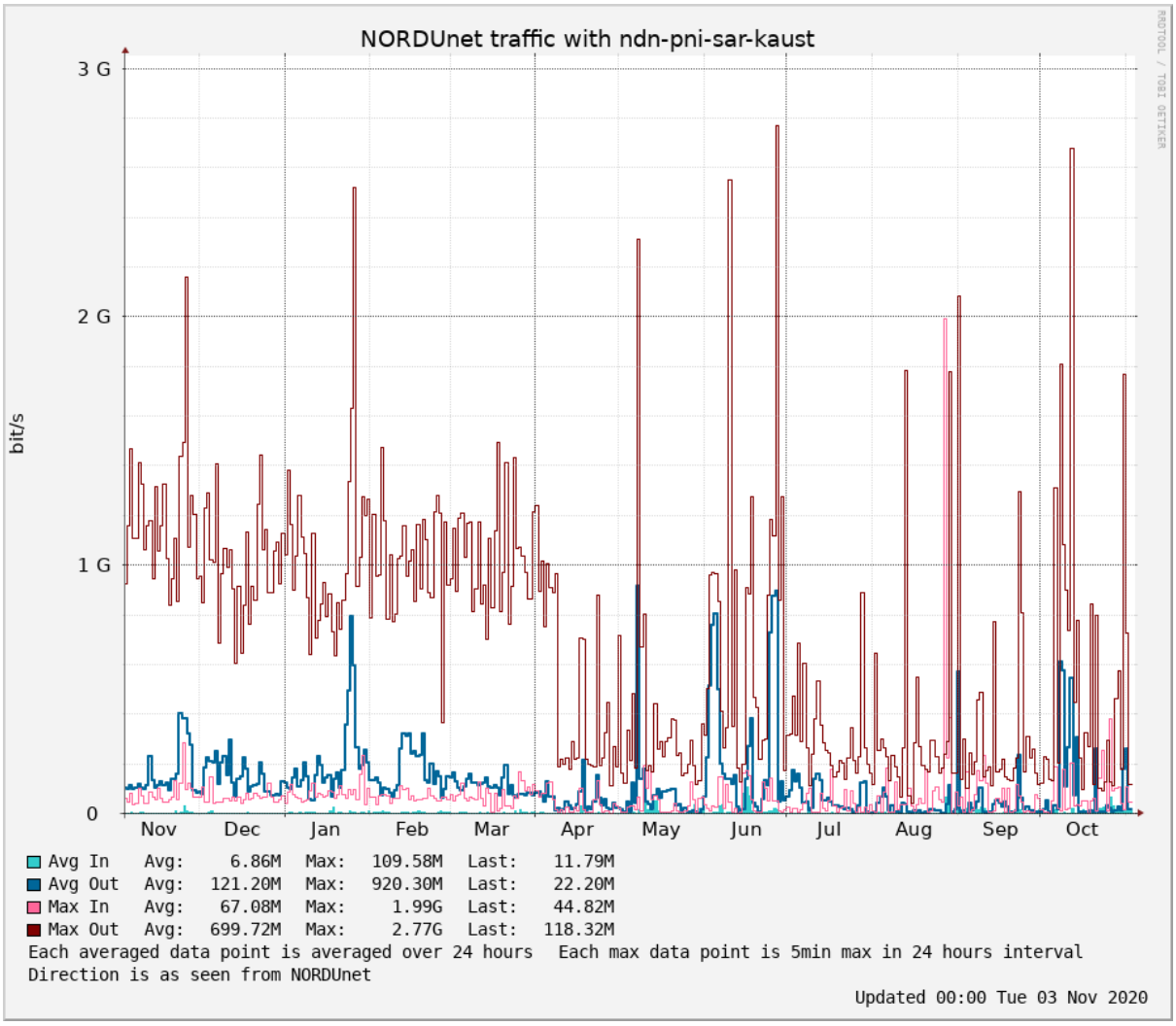

Fig. A.1. KAUST with NORDUnet link traffic.

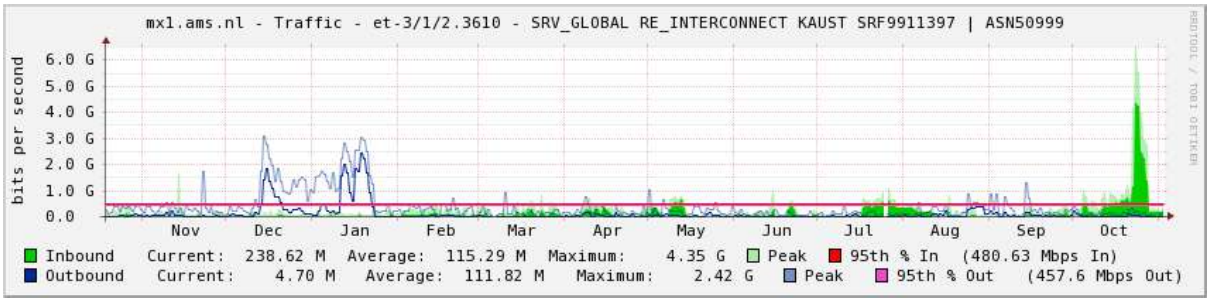

Fig. A.2. KAUST with GÉANT link traffic.

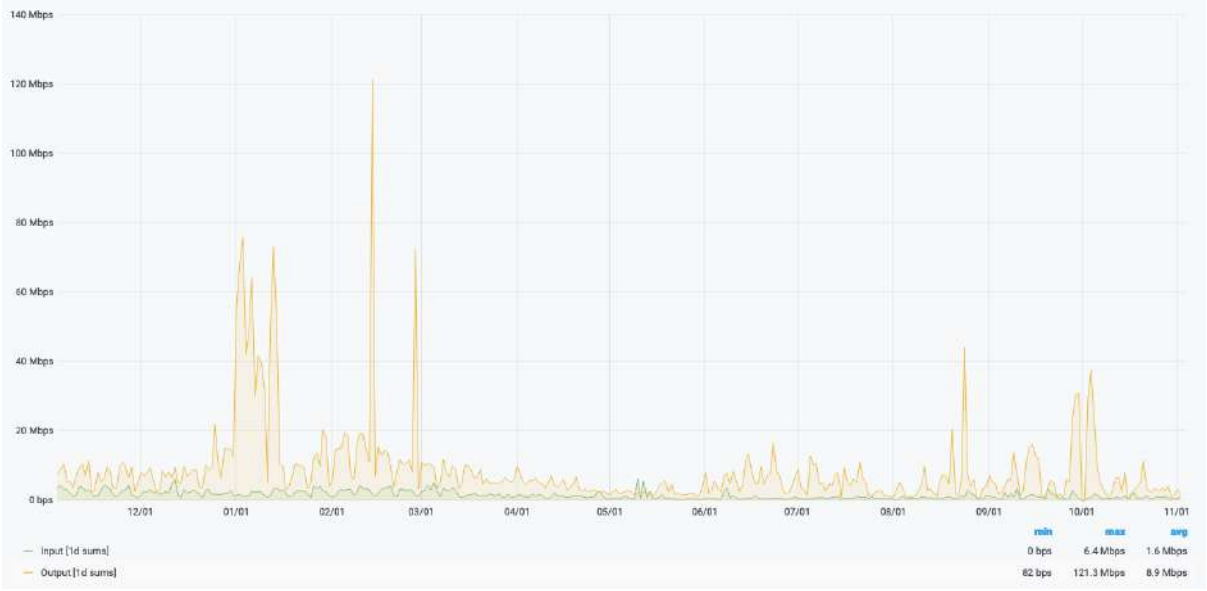

Fig. A.3. KACST-ISU with Internet2 link traffic.

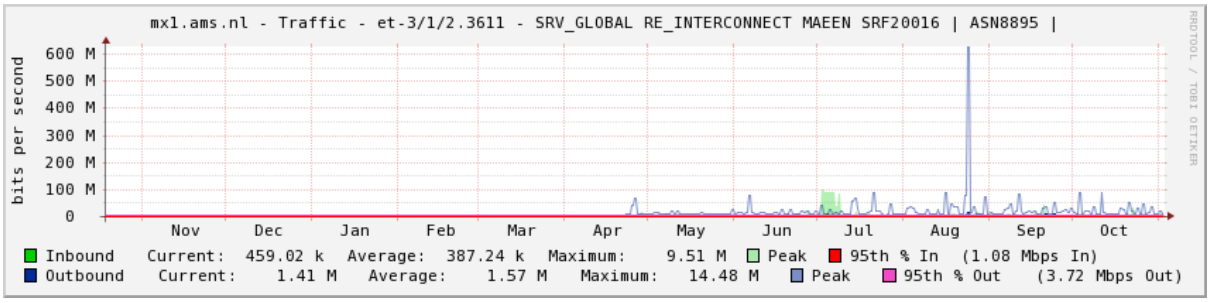

Fig. A.4. KAUST with GÉANT link traffic.

Appendix B

Sample of Collected Data from GÉANT Side

Table B.1. SINET sample inbound and outbound traffic in bits per second.

Date	Inbound	Peak	Outbound	Peak
9/1/20 1:00	1.93E+09	4.80E+09	3.62E+09	7.07E+09
9/1/20 3:00	1.37E+09	2.45E+09	5.47E+09	2.34E+10
9/1/20 5:00	1.57E+09	3.94E+09	3.46E+09	7.64E+09
9/1/20 7:00	1.66E+09	2.26E+09	2.29E+09	5.97E+09
9/1/20 9:00	2.11E+09	3.66E+09	2.52E+09	8.83E+09
9/1/20 11:00	1.59E+09	2.53E+09	6.10E+09	2.31E+10
9/1/20 13:00	1.32E+09	2.74E+09	6.63E+09	1.34E+10
9/1/20 15:00	1.79E+09	4.23E+09	7.11E+09	1.93E+10
9/1/20 17:00	2.46E+09	5.00E+09	3.00E+09	5.53E+09
9/1/20 19:00	1.31E+09	2.16E+09	2.24E+09	3.81E+09
9/1/20 21:00	1.44E+09	3.21E+09	2.36E+09	4.89E+09
9/1/20 23:00	1.21E+09	2.95E+09	2.45E+09	5.51E+09
9/2/20 1:00	1.61E+09	4.38E+09	2.24E+09	3.48E+09
9/2/20 3:00	1.96E+09	4.10E+09	3.67E+09	9.06E+09
9/2/20 5:00	1.03E+09	1.61E+09	3.73E+09	1.26E+10
9/2/20 7:00	2.00E+09	6.55E+09	3.42E+09	9.17E+09
9/2/20 9:00	1.54E+09	2.46E+09	2.45E+09	5.49E+09
9/2/20 11:00	1.56E+09	2.71E+09	2.79E+09	6.51E+09
9/2/20 13:00	2.06E+09	4.20E+09	3.59E+09	5.61E+09
9/2/20 15:00	1.35E+09	2.36E+09	6.85E+09	1.48E+10
9/2/20 17:00	1.80E+09	4.59E+09	6.28E+09	1.48E+10
9/2/20 19:00	1.14E+09	2.89E+09	3.57E+09	5.79E+09
9/2/20 21:00	2.00E+09	4.39E+09	6.06E+09	1.18E+10

Table B.2. AARNet sample inbound and outbound traffic in bits per second.

Date	Inbound	Peak	Outbound	Peak
9/1/20 1:00	5.61E+08	1.77E+09	8.52E+08	1.27E+09
9/1/20 3:00	3.86E+08	1.52E+09	1.12E+09	1.85E+09
9/1/20 5:00	2.61E+08	5.79E+08	1.28E+09	2.83E+09
9/1/20 7:00	2.57E+08	6.61E+08	9.97E+08	2.83E+09
9/1/20 9:00	2.62E+08	6.48E+08	1.26E+09	3.09E+09
9/1/20 11:00	2.77E+08	5.71E+08	1.87E+09	4.83E+09
9/1/20 13:00	3.36E+08	6.14E+08	1.21E+09	2.20E+09
9/1/20 15:00	3.05E+08	1.56E+09	9.92E+08	1.96E+09
9/1/20 17:00	4.25E+08	1.75E+09	8.81E+08	2.85E+09
9/1/20 19:00	3.83E+08	9.17E+08	1.56E+09	3.52E+09
9/1/20 21:00	3.80E+08	8.90E+08	1.35E+09	3.16E+09
9/1/20 23:00	5.61E+08	1.32E+09	1.21E+09	3.31E+09
9/2/20 1:00	3.87E+08	1.08E+09	1.27E+09	4.15E+09
9/2/20 3:00	6.70E+08	1.44E+09	1.58E+09	4.15E+09
9/2/20 5:00	1.23E+09	1.52E+09	2.06E+09	4.48E+09
9/2/20 7:00	1.15E+09	1.42E+09	2.13E+09	3.30E+09

9/2/20 9:00	1.22E+09	1.68E+09	1.32E+09	2.54E+09
9/2/20 11:00	1.30E+09	1.74E+09	1.36E+09	3.68E+09
9/2/20 13:00	1.25E+09	1.63E+09	8.86E+08	1.75E+09
9/2/20 15:00	1.24E+09	1.44E+09	1.11E+09	2.59E+09
9/2/20 17:00	1.43E+09	1.99E+09	9.81E+08	3.31E+09
9/2/20 19:00	1.33E+09	1.47E+09	1.85E+09	3.38E+09
9/2/20 21:00	1.35E+09	2.09E+09	1.94E+09	3.62E+09

Table B.3. KAUST sample inbound and outbound traffic in bits per second.

Date	Inbound	Peak	Outbound	Peak
9/1/20 1:00	1.01E+06	1.19E+06	1.16E+08	1.35E+08
9/1/20 3:00	8.47E+05	1.06E+06	9.55E+07	1.26E+08
9/1/20 5:00	9.89E+04	1.17E+05	5.27E+06	5.61E+06
9/1/20 7:00	3.58E+06	3.84E+07	6.04E+06	1.04E+07
9/1/20 9:00	2.24E+06	4.57E+06	9.23E+06	1.25E+07
9/1/20 11:00	2.36E+06	1.34E+07	1.74E+07	1.46E+08
9/1/20 13:00	7.53E+05	2.72E+06	1.17E+07	4.73E+07
9/1/20 15:00	2.18E+07	9.60E+07	1.18E+08	1.85E+08
9/1/20 17:00	1.50E+07	9.60E+07	7.51E+08	8.50E+08
9/1/20 19:00	7.27E+06	8.51E+06	7.44E+08	8.45E+08
9/1/20 21:00	4.46E+06	6.39E+06	4.61E+08	6.70E+08
9/1/20 23:00	2.44E+06	3.38E+06	1.62E+08	2.82E+08
9/2/20 1:00	1.05E+06	1.99E+06	1.10E+08	1.50E+08
9/2/20 3:00	9.48E+05	2.37E+06	1.06E+08	1.79E+08
9/2/20 5:00	2.22E+06	2.54E+06	1.58E+08	1.91E+08
9/2/20 7:00	1.91E+06	2.47E+06	1.51E+08	1.87E+08
9/2/20 9:00	1.26E+06	2.56E+06	1.08E+08	1.70E+08
9/2/20 11:00	3.45E+06	3.39E+07	1.47E+08	2.53E+08
9/2/20 13:00	2.18E+06	3.65E+06	1.03E+08	1.32E+08
9/2/20 15:00	3.12E+06	4.41E+06	1.47E+08	1.90E+08
9/2/20 17:00	2.66E+06	4.10E+06	1.48E+08	1.77E+08
9/2/20 19:00	2.60E+06	3.87E+06	1.41E+08	1.82E+08
9/2/20 21:00	3.01E+06	4.53E+06	1.42E+08	1.72E+08

Table B.4. KACST-ISU (MAEEN) sample inbound and outbound traffic in bits per second.

Date	Inbound	Peak	Outbound	Peak
9/1/20 1:00	5.62E+04	1.85E+05	9.32E+05	8.50E+06
9/1/20 3:00	4.50E+04	1.34E+05	8.89E+05	8.48E+06
9/1/20 5:00	5.44E+04	3.30E+05	8.62E+05	8.49E+06
9/1/20 7:00	5.40E+04	2.06E+05	1.07E+06	8.39E+06
9/1/20 9:00	1.55E+05	5.97E+05	1.47E+06	9.03E+06
9/1/20 11:00	4.29E+05	2.33E+06	1.56E+06	9.30E+06
9/1/20 13:00	3.01E+06	7.35E+06	3.72E+06	1.32E+07
9/1/20 15:00	4.54E+06	8.81E+06	1.26E+06	9.19E+06
9/1/20 17:00	1.31E+06	7.97E+06	1.04E+06	8.65E+06
9/1/20 19:00	8.31E+04	1.00E+06	1.00E+06	8.76E+06
9/1/20 21:00	1.16E+05	3.50E+05	1.71E+06	9.70E+06

9/1/20 23:00	1.10E+05	4.69E+05	1.31E+06	8.98E+06
9/2/20 1:00	8.24E+04	4.18E+05	8.85E+05	8.50E+06
9/2/20 3:00	1.76E+05	6.72E+05	8.59E+05	8.45E+06
9/2/20 5:00	3.73E+04	1.53E+05	8.67E+05	8.70E+06
9/2/20 7:00	1.04E+05	5.70E+05	1.14E+06	8.66E+06
9/2/20 9:00	2.18E+05	6.79E+05	1.41E+06	8.86E+06
9/2/20 11:00	2.70E+05	6.58E+05	2.02E+06	7.69E+06
9/2/20 13:00	3.90E+05	1.38E+06	1.52E+06	9.85E+06
9/2/20 15:00	5.36E+05	1.84E+06	1.21E+06	1.01E+07
9/2/20 17:00	2.48E+05	1.32E+06	9.79E+05	8.56E+06
9/2/20 19:00	1.12E+05	4.33E+05	1.01E+06	8.57E+06
9/2/20 21:00	2.49E+05	5.16E+05	8.95E+05	8.33E+06

Appendix C

Income Sources Data for Some GÉANT Partner Countries

Table C.1. Percentage of income sources for some GÉANT partner countries.

Country	Users/Clients	National governments and public	EU	Other sources
Bulgaria	0	0	50	50
Greece	0	90	10	0
Lithuania	0	80	0	20
Montenegro	0	69	31	0
Romania	0	100	0	0
Slovenia	0	99	1	0
Spain	0	97	3	0
Turkey	0	97	3	0
Croatia	1	93	5	1
Portugal	3	92	5	0
Estonia	4	96	0	0
Slovakia	9	87	3	1
Luxembourg	10	68	20	2
Ireland	14	79	5	2
France	15	77	4	4
Czech Republic	16	47	36	1
United Kingdom	16	83	0	1
Belgium	21	79	0	0
Cyprus	27	53	20	0
Hungary	30	50	20	0
Finland	50	45	2	3
Norway	55	29	3	13
Switzerland	57	6	4	33
Netherlands	65	31	4	0
Sweden	67	27	0	6
Latvia	73	10	17	0
Iceland	90	0	0	10
Italy	92	6	2	0
Germany	93	1	3	3
Austria	100	0	0	0
Denmark	100	0	0	0

الشبكات الوطنية للبحث والتعليم

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المستخلص. توفر الشبكات الوطنية للبحث والتعليم خدمات حيوية لمجتمع البحث والتعليم. تركز هذه الخدمات بشكل أساسي على زيادة التعاون المتبادل والاشتراك في الموارد. يؤدي هذا في النهاية إلى استخدام أفضل للموارد المشتركة ويعزز جودة البحث العلمي. ومع ذلك، فإن مستوى نضج هذه الشبكات يختلف من بلد إلى آخر. في هذه الورقة، ندرس الوضع الحالي للشبكات البحثية والتعليمية في المملكة العربية السعودية. وجدنا أن هناك جهتين سعوديتين لهما اتصالات مع الشبكات البحثية والتعليمية العالمية، وهما جامعة الملك عبد الله للعلوم والتقنية، ومدينة الملك عبد العزيز للعلوم والتقنية – وحدة خدمات الإنترنت. كانت جامعة الملك عبد الله للعلوم والتقنية أول جهة في المملكة العربية السعودية تحصل على اتصال مع الشبكات البحثية والتعليمية العالمية في عام ٢٠١١م. وكان أول اتصال خارجي للجهة الثانية، ممثلة في مدينة الملك عبدالعزيز للعلوم والتقنية، في عام ٢٠١٦م، التي تجدر الإشارة إلى أنها مزود خدمة شبكة الشبكات (الإنترنت) لما يقرب من ٥٠ منظمة محلية مختلفة. لقد استخدمنا أدواتٍ وطرائق إحصائية للمقارنة بين الجهتين، مثل كمية البيانات الواردة والصادرة إلى الشبكات البحثية والتعليمية العالمية. لقد لاحظنا أن أكثر من ٩٥٪ من حركة تبادل البيانات من وإلى المملكة العربية السعودية تتم بين جامعة الملك عبدالله والشبكات البحثية والتعليمية العالمية. نأمل أن يساعد هذا البحث في تقديم نظرة عامة أفضل على الوضع الحالي لشبكات البحث والتعليم في المملكة العربية السعودية. كما نأمل أن يضيء بحثنا الطريق لتطبيق هذا النوع من الشبكات بشكل أفضل في المملكة العربية السعودية في المستقبل القريب إن شاء الله.

الكلمات المفتاحية: الشبكة الوطنية للبحث والتعليم، المملكة العربية السعودية، شبكة الشبكات، حركة البيانات الواردة والصادرة، مزود الخدمة، أدوات إحصائية.