Circuit Switching versus Packet Switching

Manfred Sneps-Sneppe

Abstract—**Communication specialists around the world are facing the same problem: shifting from circuit switching (CS) to packet switching (CS). Communication service providers are favoring "All-over-IP" technologies hoping to boost their profits by providing multimedia services. The main stakeholder in this field of the paradigm shift is the industry itself: packet switching hardware manufacturers are going to earn billions of dollars and thus pay engineers and journalists many millions for the promotion of the new paradigm. However, this drive for profit is tempered by life itself. This article is devoted to the discussion of the telecommunications development strategy. We will provide examples to illustrate the difficulties that complicate the transition from CS to PS and make us question the feasibility of shifting the telecommunications paradigm at all.**

Keywords— **circuit switching; packet switching; network-on-a-chip; SS7; intelligent network; softswitch; global information grid.**

I. Introduction

On world telecom market. Figure 1 shows the world telecom market revenue shares in 2015 especially for new revenue opportunities relating to nontraditional services [1]. The sum of nontraditional services revenue attributable to telecom carriers is expected to amount to 8.1% of worldwide traditional telecom services revenue in 2015. Nontraditional services are expected to contribute most in terms of increasing top-line revenue, and include media/entertainment, public cloud computing and IT services.

Figure 2 shows Gartner's strategic map of major new market opportunities and contrasted them with traditional telecom services, such as consumer and enterprise voice, mobile voice, consumer fixed broadband and messaging. The size of each bubble represents the global market segment revenue in 2015. By plotting the projected EBIT (earnings before interest and taxes) margin for 2015 against the compound annual growth rate (CAGR) for 2011 to 2015 on a single chart, the picture can gauge the market opportunity, and the business impact of each nontraditional service.

New services such as M2M communications, mobile advertising and mobile application stores are of special interest. "Mobile Advertising" includes display ads (on mobile Internet and applications), searches (maps), audio or video ads received (not broadcast), and SMS/MMS/IM elements inserted into user-generated messages. However, it excludes SMS/MMS/IM-based ads that are pushed to users. "Mobile Application Store" considers only revenue generated by applications, which include magazine subscriptions and e-books. It excludes any kind of "content," such as music, ring tones and wallpapers. From an EBIT perspective, nontraditional services will amount only to 4.0% of worldwide traditional telecom services EBIT in 2015, but are fast growing, e.g. see 80% gain of M2M communications.

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Manfred Sneps-Sneppe is CEO of AbavaNet (e-mail: sneps@ mail.ru).

The rise of packet switching. Let us start the talk about CS vs. PS opposition with historical remarks. The formation of the Bell Company in 1876 marked the arrival of the Public Switched Telephone Network (PSTN). From a network that supported just voice calling, it has today evolved to offer advanced services. It represents $250 billion in network investment and hundreds of billions of dollars in annual revenues. The Internet originated in the 1960s as ARPANET from a packet-switched research project sponsored by Advanced Research Project Agency (ARPA). IP networks and PSTN employ conceptually different architectures. But IP networks are in a rising phase as Figure 2 shows.

As for today, the current telecommunication infrastructure consists of a transport network - made of circuit-switched TDM (time division multiplexing) lines and electronic switches, SONET (or SDH) and DWDM devices – on top of which run multiple service networks. The service networks include the voice network (circuit switched), and the IP network (datagram, packet switched). When considering whether IP has or will take over the world of communications, we need to consider both the transport and service layers. In what follows, we will be examining which of two outcomes is more likely: Will the packet-switched IP network grow to dominate and displace the circuit switched transport network; or will the (enhanced) circuit-switched TDM and optical switches continue to dominate the core transport network?

The rest of this survey-type paper is organized as follows. We are considering three examples regard difficulties that complicate the transition from CS to PS.

(1) The emergence of new trends in microelectronics: the construction of network-on-a-chip (NoC) oriented towards packet switching, where a return to circuit switching is observed.

(2) The telecom strategy: to use packet switching at the edges of the network and circuit switching at the core of the network.

(3) The development of the global information grid (GIG) - the United States Department of Defense communications network, the world's largest departmental

network (as a case study), analyzing difficulties that complicate the GIG transition from CS to PS, which is still based on SS7 signaling and an intelligent network.

In Section 2, the emergence of new trends in microelectronics is considered: the development of networks-on-a-chip (NoC) oriented towards packet switching, where a return to circuit switching is observed. Section 3 is devoted to telecom strategy: the use of packet switching at the edges of the network and circuit switching at the core of the network. In Section 4 we consider the development of the global information grid (GIG) - the United States Department of Defense communications network, the world's largest departmental network, as a case study. The paper is the extended version of our recent paper [2].

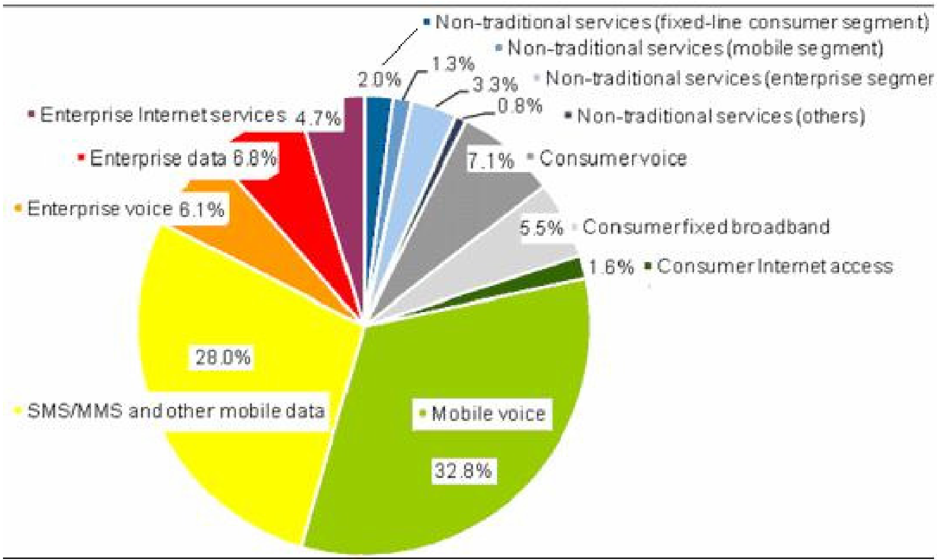

Fig. 1. Worldwide Telecom Carriers — Distribution of Service Revenue in 2015 [1].

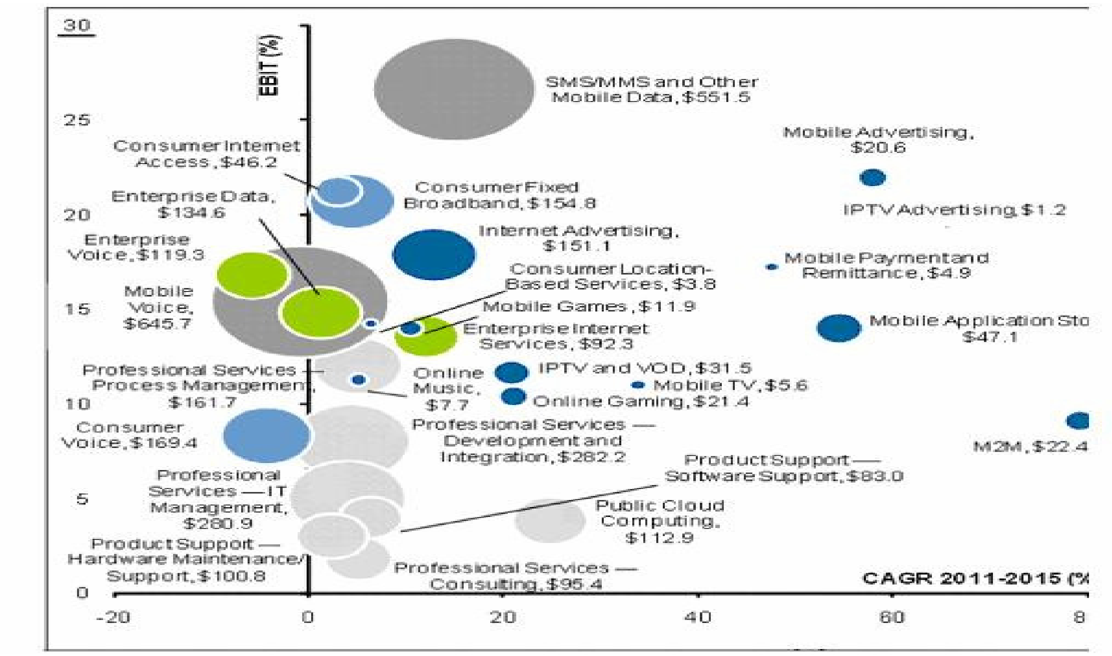

Fig. 2. Strategic Mapping of Market Opportunities, Worldwide (Billions of Dollars) [1].

II. NETWORK-ON-A-CHIP: CS VERSUS PS

Consider the confrontation of CS and PS supporters in one particular but very important area — microelectronics. NoC schemes were initially developed for packet switching, while considering circuit switching as a side option. However, in the latest years, there are works denoting the opposite: in the NoC market, circuit switching (CS) products can take the field from packet switching (PS) products.

Figure 3 shows an example of a complex circuit: a so-called network on a chip (NoC) [3]. A single crystal houses a lot of familiar elements: the central processing unit (CPU); the memory (MEM); the input/output (I/O); and the USB interface, Ethernet, and others. They mainly communicate using buses (bus), but the question that relates to the topic of this article is how to build the central part — the switching network between the buses.

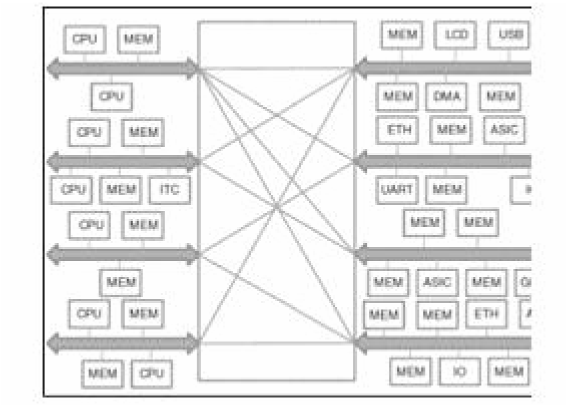

Fig. 3. Single-crystal microchip (NoC) example

The Intel example. The switching element of the modern NoC reaches considerable dimensions. As an illustration of the state of the microelectronics, we refer to the latest development of Intel [4]. In February 2014, Intel announced the development of a phenomenal chip that contains a network consisting of a matrix of 256 nodes (switching field of 16 x 16). This network is a high-performance hybrid switch board with 202 terabit/s bandwidth. This chip is based on 22-nm trigate CMOS technology. It is important that this chip is able to switch not only packets (as a standard now) but circuits as well.

Packet switching (PS NoC). Figure 4 shows a No network for packet switching. Each node S comprising a 4x4 switch board is a router; it has four inputs, four outputs, and a certain resource (CPU, memory, I/O device) that communicates with the S node via the resource network interface (RNI). In the packet switching (PS) mode, there is a buffer allocated for each input. The operations of the S node are controlled by Arbiter. The operation of message sending is the consistent transmission of packets through a chain of routers

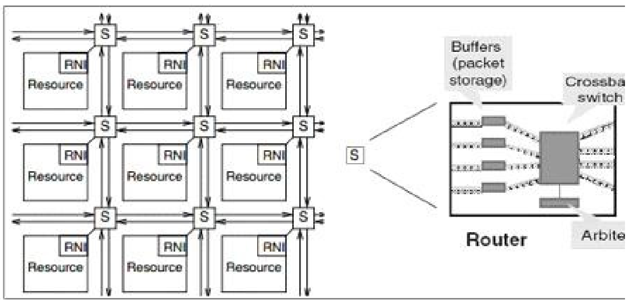

Fig. 4. Network on a chip with 9 nodes (left); each node S represents a router with 4 inputs and outputs (right).

Figure 5 illustrates the mechanism for transmitting messages (Message) received by the chip input. Next, they are divided into smaller parts due to the numbers of bits for the devices (usually, that is the number of parallel wires between blocks). The messages are divided into packets (Packet), and those in turn are divided into smaller units: Flit and Phit (usually, the lengths of Flit and Phit are the same). Phit is a unit of data that is transferred between nodes in a single cycle of the chip.

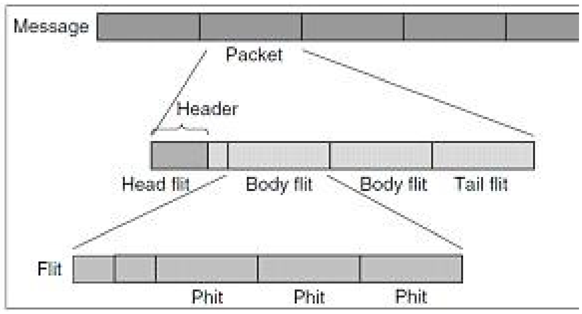

Fig. 5. Dividing messages into shorter pieces while the message is transmitted by the chip

Circuit switching (CS NoC). In the circuit switched (CS) mode, the physical channel (from the network input to the output) is reserved until data transmission starts. When the message subject is being transmitted through the network, it reserves (occupies) the path for the message transmission. Furthermore, this method, as compared with packet switching, eliminates the need to transmit the service information (head flit and tail flit) for each packet.

The essence of circuit switching is the following: the Arbiter controller determines the input, and the multiplexer, the output of the bit stream (Phit) in this cycle of the chip.

So, let us summarize the features of CS NoC and PS NoC. In circuit switching mode, there are the following:

- A physical channel (from the network entry to exit) is reserved before starting the transmission of data.
- When the message subject is being transmitted through the network, it reserves (occupies) the path for the message transmission.
- The main benefit is low latency in message transmission after reserving the channel.

Disadvantages are the path continues to be unavailable during the stage of reserving and freeing the channel after the completion of the transmission, and the network in CS mode cannot be scaled with sufficient flexibility.

In packet switching mode, there are the following:

- Packets can be transmitted in different ways and can come with different delays.
- Each package should be complemented with service information (head flit and tail flit).
- Transmission starting takes no time, and the delay is variable, which leads to collisions in routers.

It is difficult to meet the QoS requirements.

Below we present the results of the first substantial experiments on comparing the CS NoC and PS NoC capacity.

On CS NOC advantages: MPEG-4 decoder (Taiwan). Let's start with a specific mass product—an MPEG-4 decoder. The international standard MPEG-4 was introduced in 1998. The MPEG-4 standard is mainly used for broadcasting (video streaming), recording movies onto a CD, and for video telephony (videophones) and broadcasting, which actively use digital video and audio compression.

In 2006, the engineers of a Taiwan university presented

MPEG-4 decoder prototypes in two implementations: CS NoC and PS NoC based on 0.18 μm technology [5]. The test results clearly show the advantage of circuit switching for NoC. The CS NoC option surpasses PS NoC in all the indices (Table 1). The most notable is the difference in power consumption — by 45 times.

Table 1. Experimental results for two different MPEG-4 decoder architectures

	CS NoC	PS NoC
Surface (μm^2)	56.26×10^3	649.27×10^3
Power consumption (μW)	260.6	11793.69
Delay (ns)/switch	3.48	29.66
Bandwidth (10^6 ns)	2.16	12.04

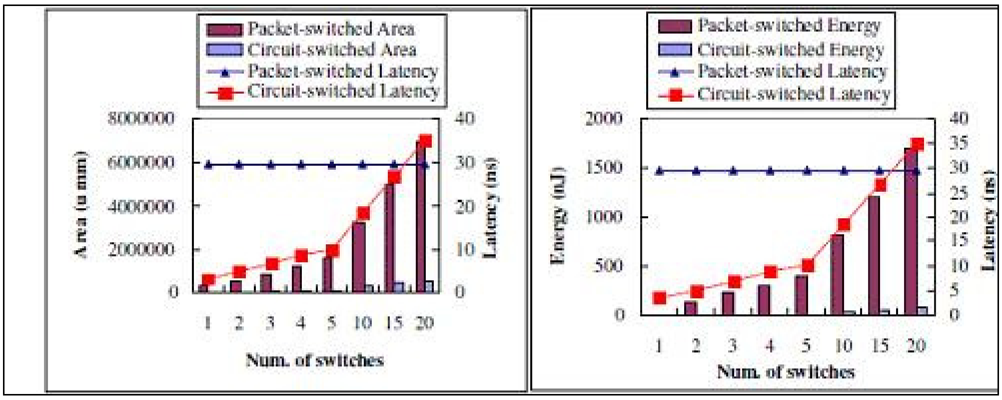

Fig. 6. CS and PS NOC: area, energy and latency characteristics.

The left-hand side of Figure 6 shows the area, energy and latency characteristics of the circuit-switched NOC and the packet-switched NOC. In the packet-switched NOC, the latency means the time of transmitting one message from one node (router or PU) to another node passing through a router. In circuit-switched NOC, the latency means the time of transmitting one message from one core to another core passing through switches. From the experimental results we see that the delay of one packet-switched router is much larger than that of the switch because the former one consists of several complex components for processing packets.

The right-hand side of Figure 6 shows the energy and latency characteristics of the circuit-switched NOC and the packet-switched NOC. The energy means the total energy consumption of completing MPEG-4 application workloads in line-shape topologies with different number of switches. From these two figures we conclude that although the packet-switched NOC is high performance and high throughput, the area and the power consumption will significant increased when the scale of the network increases.

In summary, the advantages of packet-switched NOC are: scalability and high throughput, however, they still suffer from long end-to-end latency, high implementation costs and unnecessary power consumption. Major advantages of the proposed circuit-switched interconnection architecture are lower power consumption, lower communication latency than that of the packet-switched NOC. If the scale of the SOC is just under few tens of cores, using the proposed circuit-switched NOC will be more attractive than the packet-switched NOC.

On CS NOC advantages: a Stockholm experience. In 2013, Swedish engineers (the Royal Institute of Technology, Sweden) presented the results of comparing three NoC solutions [6]:

(1) CS NoC with a 4 x 4 switching field;

(2) PS NoC with the same field: 4 virtual channels and 4 buffers (ps_v4_b4); and

(3) PS NoC: 16 virtual channels and 16 buffers (ps_v16_b16).

The measurements have shown (Fig. 7) that, in a vast range of loads, circuit-switched CS NoC is more effective. If the packets are longer than 500–800 bytes, then circuit-switched CS NoC is more effective. The first packet switching PS NoC option (ps_v4_b4) has the advantage only in case of packets of only 500 bytes, while the second PS NoC option (ps_v16_b16) retains its advantage for packet lengths up to 800 bytes. At a packet length of 5120 bytes, the capacity of both PS NoC options is the same.

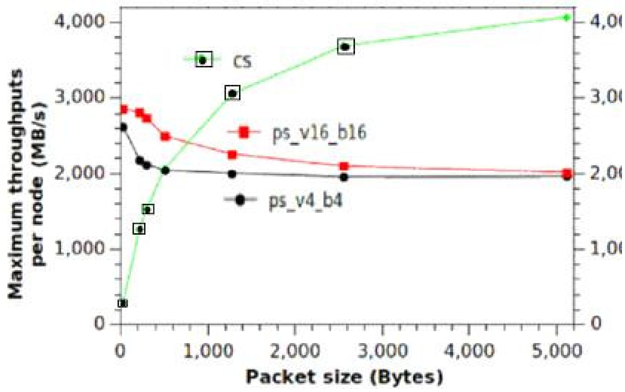

Fig. 7. In a vast range of loads, circuit-switched CS NoC is more effective than packet-switched PS NoC

III. Switching Technology trends

In order to study how the capacity of links and switches will scale in the future, one needs to understand the evolution trends of the underlying technologies used in routers and circuit switches. This enables one to foresee where bottlenecks might occur [7].

What are switching technology trends?

Internet traffic has been doubling every year since 1997. In contrast, according to Moore's law, the number of functions per chip and the number of instructions per second of microprocessors have historically doubled every 1.5 to 2 years. Historically, router capacity has increased slightly faster than Moore's law, multiplying by 2.2 every 1.5 to 2 years. This has been due to advances in router architecture and packet processing.

DRAM capacity has quadrupled on average every three years, but its frequency for consecutive accesses has been increasing less than 10% a year, equivalent to doubling every 7 to 10 years.

Finally, the capacity of fiber optics has been doubling every 7 to 8 months since the advent of DWDM in 1996.

Figure 8 shows the mismatch in the evolution rates of optical forwarding, traffic demand, electronic processing, and electronic DRAM memories. We can see how link capacity will outpace demand, but how electronic processing and buffering clearly drag behind demand. Link bandwidth will not be a scarce resource, but the information processing and buffering will be. Instead of optimizing the bandwidth utilization, we should be streamlining the data path.

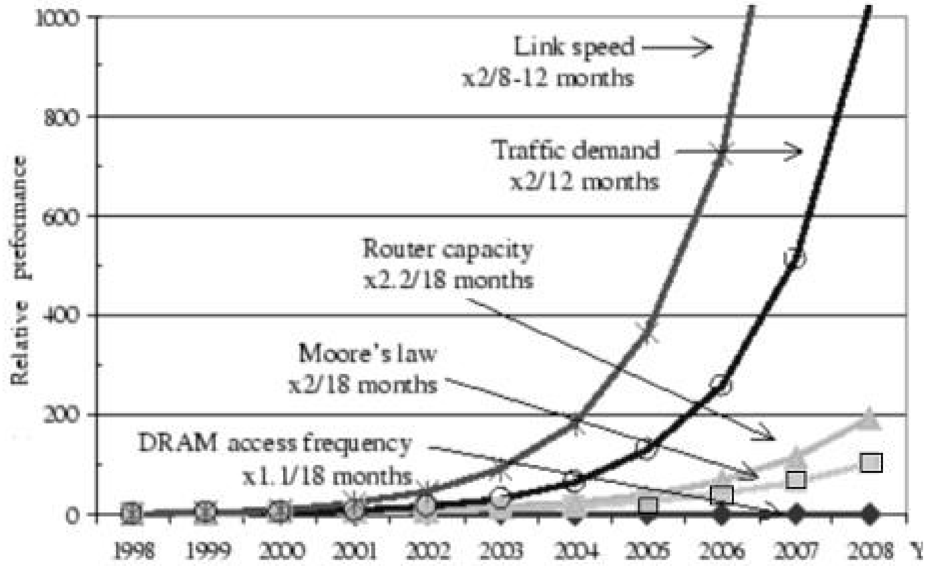

Fig. 8. Trends of traffic demand and the underlying technologies in the Internet (1998 = 100%) [7].

Figure 8 shows how an increasing performance gap could cause bottlenecks in the future. The first potential bottleneck is the memory system, the second one is information processing.

When we consider electronic circuit switches and routers, the data path of circuit switches is much simpler than that of electronic routers. This simple data path of circuit switches allows them to scale to higher capacity than equivalent electronic routers.

In general, a router has to:

1) Receive data through its ingress port and send it shortly afterwards through the appropriate egress port.

2) Routers need buffers. Routers usually need a Link Rate × Round Trip Time worth of buffers because of the way the flow control mechanisms of TCP work. For example, for an OC-768 link of 40 Gbit/s and a typical round trip time (RTT) of 250 ms, a line card needs 1.2 GBytes of memory. Dynamic RAM (DRAM) is thus used to meet this capacity requirement. Most router capacity is limited by memory availability.

3) Routers need to look up the destination address in a routing table to decide where to send a packet next, or in which queue it should be buffered.

This is confirmed by looking at the fastest switches and routers that are commercially available in the market at the time of writing (2002); one can see that circuit switches have a capacity that is 2 to 12 times bigger than that of the fastest routers, as shown in Table 2. The simple data path of circuit switches comes at the cost of having a more complex control path. However, it is the data path that determines the switching capacity, not the control path; every packet traverses the data path, whereas the control path is taken less often, only when a circuit needs to be created or destroyed.

Table 2. Bidirectional switching capacities of commercial switches, 2002 [7]

Product	Type of switch	Bidirectional switching capac
Cisco 12016	router	160 Gbit/s
Juniper T640	router	320 Gbit/s
Lucent LambdaUnite	circuit switch	320 Gbit/s
Ciena CoreDirector	circuit switch	640 Gbit/s
Tellium Aurora 128	circuit switch	1.28 Tbit/s
Nortel OPTera HDX	circuit switch	3.84 Tbit/s

Comparing the switches of equal throughput, it is reasonable to expect that since packet switches do much more, it would come at the cost power and price. Table 3 compares two high capacity switches: packet switch Cisco CRS-1 and Ciena TDM switch; the former consumes 7 times the power and costs 10 times more (to multiple cost numbers with $1000 to get absolute values).

Table 3. Comparison of power consumption and price, 2012 [8].

	TDM Switch	Packet Switch
	Ciena CoreDirector	Cisco CRS-1
B/w	640 Gbps	640 Gbps
Power	1440 W	9630 W
Price	83.73	884.35

Comments on future circuit switching technology. The key question is: will the packet-switched IP network grow to dominate and displace the circuit switched transport network; or will the (enhanced) circuit-switched TDM and optical switches continue to dominate the core transport network?

If we are looking for simplicity, we can do well to look at how circuit-switched transport switches are built. First, the software is simpler. The software running in a typical transport switch is based on about three million lines of source code, whereas Cisco's Internet Operating System (IOS) is based on eight million, over twice as many. Table 4 explains the complexity of router (packet switch).

Table 4. Comparison of packet and circuit switching functions [8].

TDM Switch	Packet Switch	
Phy	Phy	Policing
TSI	Parsing	Policy Routing
Fabric	Lookup	Congestion Avoidance
	Modifications	QoS
	Fabric	Sampling & Mirroring
	ACLs	Hashing
	Queuing	

TDM swtches use simpler hardware and software, electronic circuit switches consume less power, allowing more capacity to be placed in a single rack. It should come as no surprise that the highest capacity commercial transport switches have two to twelve times the capacity of an IP router (see Table 2), and sell for about half to 1/12 per gigabit per second [9]. So even if packet switching might be simpler for low data rates, it becomes more complex for high data rates.

Packet switching would be used in the edges of the network as well as in those links where bandwidth is scarce (such as some satellite and wireless links, and underwater cables). The packet-switched network should ideally gather traffic from disparate sources, and multiplex it together in preparation for carriage over a very high capacity, central, circuit-switched core. All traffic can be multiplexed towards the core, and then demultiplexed again towards the edge. At the core of the network, there seem a number of compelling reasons to use circuit switching. Circuit switching is inherently simpler than packet switching, requiring less work to forward data, and consequently will cost less as a result, will consume less power, and will take up less space. Last, but not least, circuit switching provides an easy way to adopt the huge potential of high capacity optical switches in future. Without electronics on the forwarding path, one can expect optical switches to provide abundant capacity at low cost.

Therefore, what seems more likely is that packet switching will continue to exist at the edge of the network, aggregating and multiplexing traffic from heterogeneous sources for applications that have no delay or quality requirements [9]. At the core of the network, we expect the circuit switched transport network to remain as a means to interconnect the packet switched routers, and as a means to provide high reliability, and performance guarantees. Over time, more and more optical technology will be introduced into the transport network, leading to capacities that electronic routers cannot achieve.

IV PENTAGON'S GIG AS A CASE

Let us use the Pentagon's global information grid (GIG) as a case, as a bright illustration of many troubles on the road from circuit switching to packet switching.

Joint Vision 2010 strategic plan: orientation towards AIN. The Defense Information Systems Network (DISN) belonging to the Pentagon is the world's largest departmental network. The DISN has been developed since the early 1990s. This is a global network. It is intended to provide communication services by transmitting different types of information (voice, data, video, and multimedia) in order to perform the efficient and secure control of military, communications, intelligence, and electronic warfare media. In 1996, the state of the DISN was panned. First of all, due to the low level of integration of members of the DISN networks, significantly limiting the interaction capabilities within a single network and preventing the effective unified management of all its resources. In particular, there was noted the complexity of the interaction of stationary and field (mobile) components of the core network due to different standards being used, the types of communication channels (analog and digital), the services, and the capacity (the bandwidth of mobile components is significantly lower than that of stationary ones).

In the development of the second phase of the DISN network, the DISA agency has taken an unprecedented step for the Department of Defense (DoD): it required the usage of only the finished commercial products in the field of new information and network technologies. The emphasis was placed on open systems, which are based on national standards, and the latest commercial technologies and services available on the market (COTS, commercial-off-the-shelf).

These requirements are reflected in the 15-year program of weapons development entitled Joint Vision 2010, which the United States Joint Chiefs of Staff adopted in October 1996. Regarding the means of communication, the Advanced Intelligent Network (AIN), the highest achievement in the art of circuit switching, was chosen. This fundamental decision was reported by the DISA representative in 1999 at the International Conference on Military Communications MILCOM'99 [10]. Here is a quote from his speech:

"The future DISA networks will enjoy the benefits of IN software. AIN services will form the core of the development technology, assessment, and DoD data transmission technology. The results of the AIN services will provide the military commanders the ability to collect, process, and transmit information without interruptions in the network service. The AIN capabilities will become the cornerstone of the DoD information superiority."

Signaling system SS7 is the AIN network interlinks: SS7 provides access to databases. Intelligent Peripheral also plays an important role: its functions include tone generation, voice recognition, speech and data compression, dialing recognition, and much more, including tactical and strategic services for personnel identification. Channel switching network subscribers, as well as packet switching network subscribers, can be AIN users.

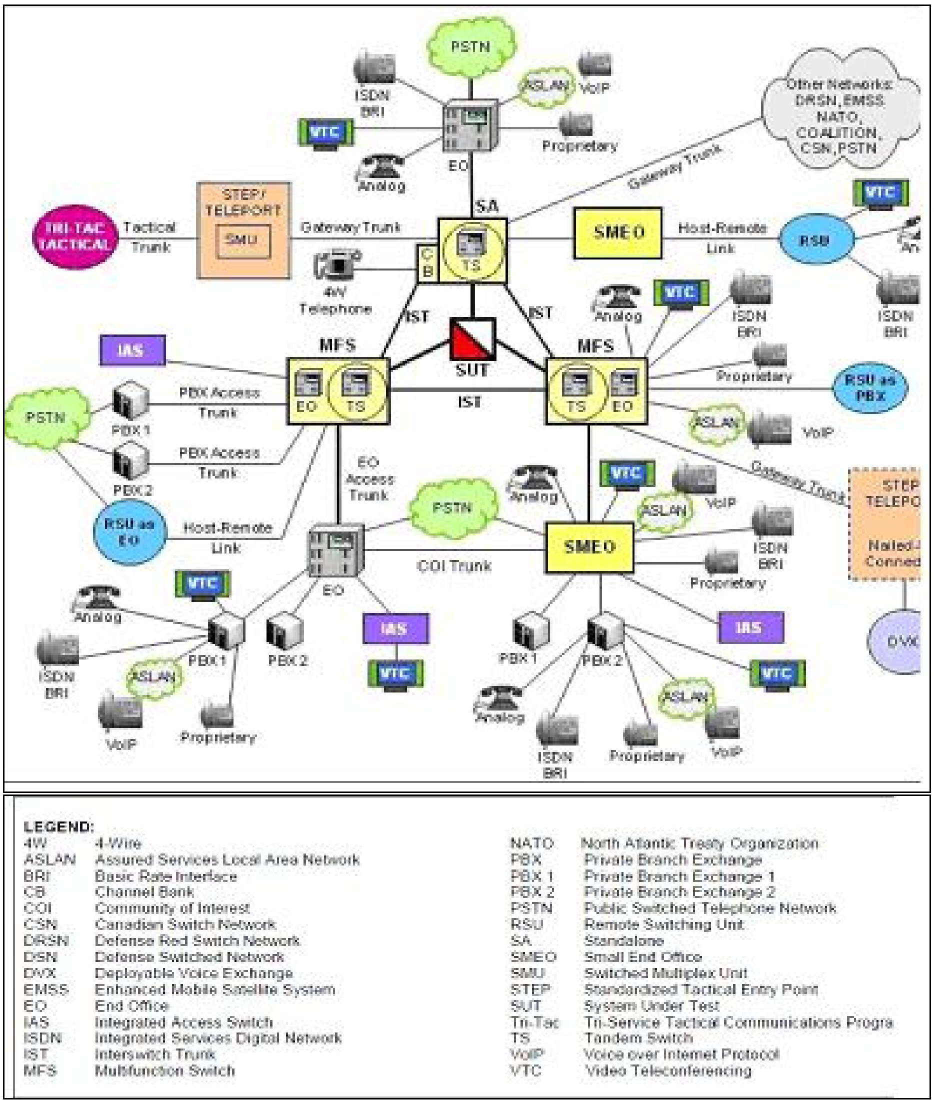

Fig. 9. Defense Switched Network (DSN) architecture. SUT=SS7 network under a test.

The SS7 network is, figuratively speaking, the nervous system of a DSN switched network. Figure 9 originates from the documentation on testing the SS7 network as the part of the DSN network conducted by Tekelec in 2011 [11]. The center of the diagram is occupied by the system under test (SUT) block, which is the SS7 network undergoing the test. That is, within the DSN network, the connections are established by means of SS7 signaling and, in the periphery, devices of any type are used. The devices are connected by any protocols: 4-wire (4W); classified LAN (ASLAN); ISDN BRI; Internet telephony (VoIP); video conferencing (VTC); any proprietary protocol; a link via communication satellites to remote telephone networks and tactical networks at theaters of military operations (STEP/TELEPORT).

From above an important conclusion follows: the DSN network tends to adopt new terminal equipment (to a large extent, this is IP media), but the SS7 network retains its central position. The presence of the SS7 network is not an obstacle to the transition to IP protocol.

Joint Vision 2010: orientation towards IP protocol. Nevertheless, in 2006, the Pentagon adopted a new plan for the next 15 years entitled Joint Vision 2020. The plan announced a DISN paradigm shift: the transition from SS7 signaling to IP protocol [12]. It is assumed that the IP protocol will be the only means of communication between the transport layer and applications. However, the timing of this transition was not announced in the plan.

As for today, GIG is based on circuit switching (more specifically, on the SONET standard for the optic cables functioning), and the information is coded according to the time division multiplexing (TDM) telephone standard. This circuit switching network is currently used by the major military communication networks of the Pentagon: the Defense Switched Network (DSN) telephone network; the Defense Red Switched Network (DRSN) secure switched network; the DISN VIDEO (DVS) video conferencing network. Besides, DISN contains four classified networks: JWICS and AFSCN (work in the ATM network); NIPRNet and SIPRNet (work in the IP network) and some more.

In 2006, looking for DISN modernization, the management of the Command, Control, Communications, and Computer Systems (C4 Systems) department in the Pentagon panned the GIG network status and announced the transition to a GIG2 network. The main disadvantages of the existing GIG network are as follows: there are many networks with different equipment, uncoordinated decisions to ensure secrecy, uncoordinated programs to conduct combat operations in different military branches, and differences in data bases. These drawbacks should be eliminated in the new version of the network: GIG2 [13]. Here is a remarkable quote from one C4 Systems representative directed to the manufacturers of military equipment in 2009: "We don't need more boxes." He reminds them that currently the military uses 40 different communication systems: "We've got enough boxes. Help us make those boxes talk to each other."

The analysis of the current state of GIG allows us to make some critical remarks.

Remark 1. How to build Joint information Enviroment. In 2012, DISA published a guidance document GCMP 2012 [14] with the new requirements for the GIG2 development methodology. The new architecture is based on the cloud computing model, and this makes it different from the previous models, which were network-centric. Unfortunately, this document doesn't contain anything regarding the fate of the previous architectural decisions: SS7 signaling, AIN network, and IP protocol. The basis for the new concept is the model based systems engineering (MBSE) and systems modeling language (SysML). The MBSE model itself is a collection of charts in the SysML language, which is similar to the universal modeling language (UML).

A reasonable question arises: will there be sufficient human resources to rebuild the existing 40 communication systems of the Pentagon, which link several satellite constellations, air and naval forces, the Army, and much more; to write uniform requirements for all the networks; to translate them into the SysML language; and to create the program code for the unified GIG2 network? It may well be that the GIG core—the SS7 signaling and AIN network—will stay there for an indefinite amount of time and thereby the generation of equipment based on the principles of circuit switching will remain as well.

Remark 2. How to keep up the DISN AIN architecture. At the MILCOM'99 Conference the representative of Lockheed Martin Missiles & Space [15], a company that is a leading developer of GIG, emphasized that AIN provides users with any services, such as: voice, data, e-mail, video, office applications, call "800". And most importantly, the report describes in detail the key role of the protocol SS7: it ensures the provision of these services, including satellite communications. Lockheed Martin's representativeeven then - more than 15 years ago noted that the explosive growth of the power of computers and web technologies in the 21st century will lead to extreme complexity in the management of the GIG network.

Recall that AIN tools have been developed at Bell Labs in the early 1980s, and introduced onto the US communications networks by Bellcore (after Bell Labs divestiture in 1984). And now - 20 years after that Pentagon's decision - revealed the extraordinary complexity of the maintenance of AIN, the core component of the global DISN. The proliferation of new weapons and new services requires continuous improvement of AIN. This is evidenced by the invitation to work at Lockheed Martin.

Industry Job Title	Mult Functional Information Systems Analyst
Job Description	Provides engineering and technical expertise on all issues relating to the specified telecommunicati networks/information systems within the DISN. Applies specialized knowledge of military unique features, specifically built into the network and its subtending hardware and software, to ensure appropriate support to the warfighter's requirement Implements or extends advanced intelligent network features into the network/system. Applies systems engineering disciplines to the provisioning of new service offerings over the network/system, often specifically tailored with military unique features.
Basic Qualifications	Requires expertise in one or more of the following devices/vendors: CISCO, Juniper, Promina, Safer Ciena, Sycamore, or Ericsson.
Security Clearance	Top Secret

Fig. 10. The invitation to work at Lockheed Martin [16].

In the long list of vacancies on the Lockheed Martin website [16] in the first place there is the search for multifunctional information systems analysts for DISN. Applicants are required to develop new services for AIN and to have an expertise in equipment from CISCO, Juniper, Promina, SAFENET, CIENA, Sycamore, Ericsson. The level of secrecy of work - the highest. That is, the company needs specialists to improve the "old" secret network core AIN (already 30 years old) and its docking with a new set of heterogeneous military devices.

Remark 3. How to keep up the DISN at all. The search for multifunctional information systems analysts could be happen, one guess, in context of the Global Systems Management Operations (GSM-O) contract. In June 2012, Lockheed Martin's Information Systems & Global Solutions Division won a competition [17], transferring the keystone GSM-O IT services contract away from Science Applications International Corporation (SAIC), and a 15-year incumbent. GSM-O pays for the worldwide support services necessary to carry out day-to-day operations of the US military's Global Information Grid networks and related services, and to update them with new technologies. The GSM-O offers programmatic, operations, engineering services, material, equipment and facilities to support lifecycle management of the GIG network. Lockheed Martin's GSM-O teammates include AT&T, ACS, Serco, BAE Systems, ManTech, and a number of other specialized and small businesses. The contract could be worth up to $4.6 billion over 7 years, making it a major win for Lockheed Martin, and a big loss for SAIC (SAIC has managed the GSM-O contract since 2001).

It is too early yet to discuss the expected success of GSM-O contract, but one deal with regard to Lockheed Martin and SAIC competition is worthy being mentioned.

Remark 4. GIG-BE project. The competition relates to the Global Information Grid Bandwidth Expansion project [18]. GIG-BE is key to realizing the DoD enterprise information environment. It is providing a worldwide, ground-based fiber-optic and IP-based network. This enables an exponential leap in ground-based voice, video and data exchange capabilities for the Defense and Intelligence Community. GIG-BE achieved full operational capability by the end of 2005 (approximately 87 Joint Staff-approved locations).

GIG-BE was awarded to SAIC in 2001 for $877 million. This contract was for the development, instantiation, and maintenance of the GIG-BE network. SAIC instantly divided the equipment and tasks into subcontracts. These subcontracts are as follows: CIENA Corporation (optical transport segment), Sycamore Networks (optical cross-connect segment), Cisco Systems (multiservice provisioning platform), Juniper Networks (core IP router portion), and By Light (installation and maintenance).

The GIG-BE contract had gone under the U.S. Congressional critic just from the beginning. Two representatives expressed concern in the selection process for a contractor to lead the GIG-BE effort. They say it was handled "irresponsibly". SAIC won the contract who eventually handed a large subset of the engineering to By Light. (Company By Light was founded in 2002 by a group of telecommunications industry veterans.) These two congressmen delivered a letter to the DoD regarding the contract. The issue was slowly forgotten, 10 years later, in 2012, SAIC had lost GSM-O contract.

Remark 5. On future role of circuit switching in the GIG network. The GIG-BE program is one costly but rather simple step towards the DISN migration to IP end-to-end. The most important step for DISN modernization is the replacing of channel switching electronic Multifunctional switches (MFS) by packet switching routers. The transition phase is based on Multifunctional SoftSwiches (MFSS). Figure 11 shows the reference model for MFSS [19]. The left side shows the traditional telephony protocols CCS7, ISDN PRI, and CAS used for connections with the "old" channel switching networks.

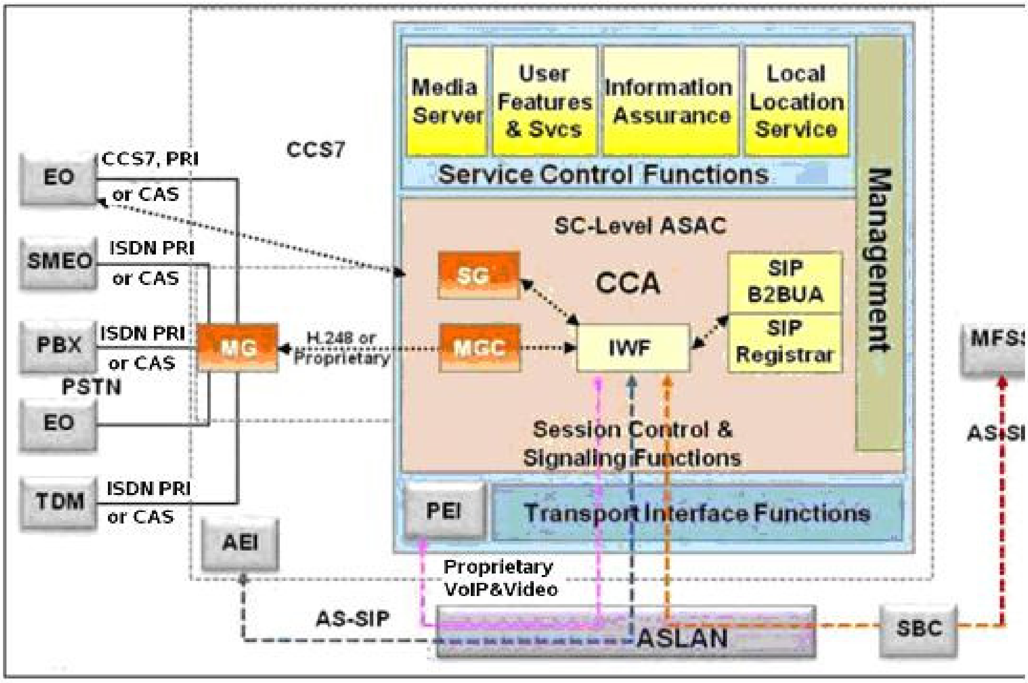

Fig. 11. Reference model for Multifunction SoftSwitch (MFSS) [19].

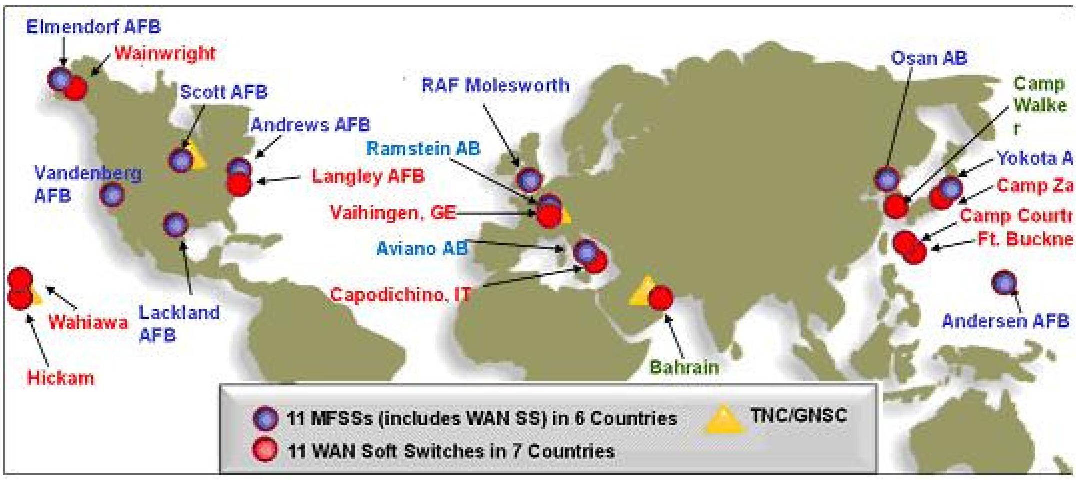

Fig. 12. Planned Wide Area Network SoftSwitch (WAN SS) and Multifunction SoftSwitch (MFSS) worldwide locations on the DISN network (by 2012) [20].

According to the DoD Plan [19], there should be only 22 large scale Cisco Systems multiservice provisioning platforms all around the world: 11 MFSSs (includes WAN SS) in 6 Countries and 11 WAN Soft Switches in 7 Countries (Fig. 12).

The following question arises here: if, as discussed above, the highest capacity circuit switch has ten times the capacity of an IP router (the fact known at the time of MFSS installation), then, in future, the Cisco Systems multiservice MFSS contract could be subject to investigation.

V Conclusion

Packet switching and IP networks are in a rising phase nowadays, but the principle of circuit switching shows its advantage in many ways.

(1) In the rapid developing field of microelectronics - network-on-a-chip (NoC), the advantage of CS NoC compared to PS NoC is manifested in the abundance of products (such as MPEG codec) that surround us in everyday life.

(2) The telecom strategy - to use packet switching in the edges of the network and circuit switching at the core of the network – is discussed.

There is an abundance of traditional telephone exchanges and major departmental communication networks around the world built on the traditional telephone circuit switching technology, and they "do not want to die." We have provided an example, the world's largest departmental communication system belonging to the United States DoD, which, in the last decade, has acquired an abundance of packet switching devices but still retains a core of traditional phone stations using SS7 signaling and the principles of an advanced intelligent network (AIN).

More broadly, it seems that both technologies—circuit switching and packet switching—will coexist for a long time yet.

In our previous papers, we reviewed a wealth of GIG experience in the context of Russian realities: how to build Russian service 112 following NG9-1-1 [21], the lessons for Rostelecom in move to IP protocol [22] and new telecommunications services exampled by GIG experience [23], how to create an unified information space for the society [24].

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