Information Switching Networks

Doan B. Hoang (dhoang@it.uts.edu.au)
Advanced Research in Networking Laboratory (ARN)
University of Technology, Sydney, Australia

Tal Lavian (tlavian@eecs.berkeley.edu)
Electrical Engineering and Computer Sciences
University of California, Berkeley, USA

Abstract.
Circuit switching and packet switching have been developed to achieve statistical gain in sharing transmission bandwidth of a "passive" transport network whereby voice and data are transported end-to-end without content modifications by the network. This paper promotes a radical switching technology that enables the network to transport as well as process/transform its contents.
In this paper we propose "information switching" as a technology for the future generation Internet that embeds networks with intelligence that is necessary to build truly cognitive information processing systems. By "cognitive information processing" we mean that network elements can intelligently and selectively deliver relevant, filtered, pre-processed information to the desired destinations. Masses of raw data can be processed and primed, on-the-move to its destination, by the network into a form that is suitable for human interaction and decision. A plausible information switching architecture that makes use of advances in information, computer, and communication technologies is also presented.

1. Introduction

Tomorrow's Internet core is mainly optical rather than electronic. Through advances in optical components and fast-developing photonic technologies, the transmission system capabilities are much bigger than the current Internet bandwidth requirements [1]. As a result, the Internet core bandwidth becomes abundant.
Tomorrow's Internet is based on network edge devices, where one can deal with various policies across administrative domains effectively, where value added services can introduced that benefit both providers and consumers; where end-to-end design principle [2] can be observed without limiting the capabilities of the network.
Tomorrow's Internet is more about intelligence networking not just passive routing. The network can prime information into a useful form before high-level decision-making process is applied.
Tomorrow's Internet makes available bountiful of computational resources [3] that can be shared on-demand by users across the globe.
Tomorrow's Internet allows selected information to be processed on-the-fly across the network based on contents, contexts, or relevant characteristics optimized for a specific application.

Yet, we are still far away from developing networked-systems that can think, learn and interact with human beings intelligently. Efforts have been made to support projects that create "cognitive information processing systems" [4]. Of particular importance are systems that can cooperate with each other to provide collective intelligence that can solve problems otherwise unsolvable individually.
All the above indications lead us to believe that higher level of switching abstraction is essential for the type of intelligence we expect from future generation networks. We propose information switching as a technology that allows networks to deal with both transporting and processing of data at an appropriate level of intelligent abstraction.

The paper first discusses the development of circuit switching, message switching, and packet switching in section 2. Section 3 presents arguments that lead to the concept of information switching. Section 4 describes an initial information switching architecture. Section 5 provides an analysis and discussion on the proposed architecture. Finally, section 6 concludes the paper with suggestions for possible applications.

2. Background on switching

In this section we briefly discuss the thinking that motivated the development of circuit, message, and packet switching. The aim is to gain some insights into the reasons for their developments.
Communications among large communities of users are best shared in the form of switching. For sheer economic and scalability reasons, it is not cost effective to allocate dedicated hardware and software to support individual communications between end entities. Realizing that not all end

entities want to establish a communication channel simultaneously, statistically sharing the facilities would make sense since the total cost would be distributed among all users.

Circuit switching (time-sharing) in telephone networks is a successful example of sharing resources to satisfy the need for voice communication between users. With circuit switching, actual end-to-end physical connection is set up before conversation can take place. The physical path is set up through a number of shared switches along the path from the source to the destination. Once the circuit is set up it is dedicated to that conversation exclusively, no other circuit can be set up that makes use of the resources dedicated for this connection.

However, circuit switching does not allow transmission resources to be used efficiently. About 40% of the time a circuit connection is idle [5], the resources dedicated to the connection cannot be made available for other connections. Furthermore, when data communication becomes dominant, it makes more economical sense to share communication bandwidth based on discrete nature of data blocks. When a user does not send a data block, the resources can be switched to other users in need.

Message switching was born whereby data is sent in meaningful blocks called messages. These messages can be checked for integrity at intermediate nodes and relayed from hop to hop until they reach their destinations. Message switching suffers several drawbacks. First, messages can be widely variable in lengths and this may cause intolerable delays to other users. Second, it is not efficient to retransmit the whole long message if it is found in error. Third, due to sequential nature of the message relay, it is difficult to utilize the resources in pipeline/parallel for better efficiency.

Packet switching was developed to address these drawbacks [6, 7]. Messages are broken into reasonable size packets that can be switched independently to their destination. Message integrity is only checked at the destination once the message is reconstructed from individual packets. The current Internet is based on packet switching.

One thing common to all these switching technologies and transport networks is that the unit of switching remains intact from a source to its destination. The contents are not processed or transformed at intermediate switching nodes.

From another perspective, the reason for circuit switching was that we were mainly concerned with the transport of real-time voice at the time. Analog representation and analog transmission seem to be a natural choice and the network was designed and optimized for voice only.
With the advance of digital technology (both switching and transmission) and of computer technology, the need for data transport became apparent. It was realized that data traffic is very bursty and efficient utilization of resources can be gained by statistically multiplexed sources at the packet level. Furthermore, with data transport, the concern was more about reliability rather than the real-time delivery aspect of the transport. Data could easily be broken into small packets, sent across the network and then reassembled reliably at the destination without regard to the timely delivery of the original message. Computer networks were designed and optimized for this type of data transport.

After some 35 years of experiences with computer communications and networking, much has been learned about the design of network, the delivery of services, routing/switching technology, computing hardware elements, software development, network management, and about creating and deploying services. The Internet has become pervasive and ubiquitous, however, to lift it up to a higher level of usability, higher level of intelligence such that it can be used as a natural extension of human capabilities; a radical look at the fundamental networking technologies is needed.

3. Why information switching?

In this section we examine several aspects that propelled us into taking a different perspective on networking.

We believe that a plausible model of intelligence is one that builds upon multi-component systems that interact through an adaptive network (network that can think). Based on this notion, we believe that it is essential to impart intelligence to the connecting network rather than considering network as a passive transport system. We believe that a radical "network that thinks" would pave the way for a visionary cognitive system. We need to impart the right type of intelligence to networks if we are to extend our capabilities beyond our intermediate environments. A networks should not be considered as a purely transport system. It should be able to deliver directed, summarized information to the end users. It must be able to interact with human being in an adaptive manner.

To this end, we believe that the network needs to view its load in terms of streams of meaningful information –information streams- rather than dumb packets or circuits. We envisage an

information stream is one that aggregates data by their common characteristics, specific applications, or similar in semantics. After all, we reason in terms of relevant pieces of information, not packet of raw, uninterpreted data! We believe that our level of abstraction deployed in current network technology is at a level too low to build an intelligent network. We believe that circuit switching and packet switching have served their purposes, however, to build higher cognitive networks based on these low level abstraction would necessitate a construction of numerous intermediate layers of intelligence whose interactions may be too complex for us to extract any useful information.
Once intelligence is embedded in the network, emerging ideas, solutions, and decisions can be expected to emerge from the network. The idea of network being able to transport information streams as well as processing them then becomes natural. Information switching is promoted as a technology that embraces our two central ideas: 1) the network payload is viewed at the right level of abstraction – i.e., in terms of information streams; and 2) the network not only can transport but also can process information streams into application-specific decision components.

For a network to be intelligent, it must possess intelligent adaptive control components and smart sensor components. The control components may take a form of a distributed library/factory of intelligent agents that can be deployed on-demand by other elements. We envisage that an intelligent network element can interact with its environment in several ways. First, it can take order from network control elements to obtain a specific agent to deal with a particular information stream. Second, it may initiate a particular agent to deal with a stream as a result of its own processing and interpretation. Third, it may interact with the control elements to create a brand new agent to deal with new situations. We assume that intensive, powerful computing/processing resource will be required to deal sensibly with information streams.
The smart sensor components allow the network element to differentiate, aggregate, merge information stream according to criteria such as specific forms, contexts, and semantics of information streams. The sensor components are also responsible for redirecting, de-aggregating, de-merging, or preserving original streams. These components may also facilitate the interaction between the network element and other agents. We envisage some forms of smart information and pattern matching are needed.

A look at several advances in networking technologies will convince us that it is now the time to shift our perspective of our computer networks and get off our current trajectory. First, there exists an abnormality in network transmission bandwidth. Through advances in optical components and fast-developing photonic technologies, the transmission system capabilities are doubling every 9 to 12 months. As a result, the Internet core bandwidth becomes abundant. A bundle of optical fibers can carry the traffic load of the entire current Internet [1]. Second, data transport over optical fiber can be over four thousand of kilometers long without the need for a repeater. This mitigates the need for elements in the core of a network? Third, storage technology has come a long way to create bigger and cheaper data storage. More and more enterprises are building enormous data centers to serve their information needs. This necessitates efficient solutions for extracting valuable information out of massive amount of data constantly. Fourth, state-of-the-art network elements equipped with reconfigurable hardware and software are capable of performing enormous amount of computation on-the-fly. There seems to be no longer a division between local processing and network processing in terms of speed and delay. These advances provide indications to how information switched network can be realized.

How intelligence is to be built into the network? Evidences indicated that there is more to a network than just L1-L3 packet switching. The network is capable of priming the inputs necessary for higher decision-making level by human beings. In fact, it is capable of sophisticated, intelligent processing on information and distills relevant information to the level useful for human consumption. New generation of network devices are able to inspect packets on the fly based on their contents. They are also equipped with either dedicated computation blades or with reconfigurable FPGA components on which dedicated processing algorithms can be downloaded, or both.

Networks can be made adaptive (programmable, active) [8, 9] without compromising the end-to-end arguments [2]. Network elements essential for information switching are edge devices located at the boundaries of an administrative network domain. It is argued that the network edge is the rightful place for valued added services, domain specific policies to be introduced. It is assuming that by introducing additional measures at these edge devices, they do not constitute a violation of the end-to-end arguments and hence the robustness of the overall network can be preserved.

There is no need to break up data into packets. What we really want the network to communicate is "intelligent information". Consequently, meaningful information stream should be the unit of data transport in an information switched network. In fact, the situation is vastly different from 35 years ago where a message of few kilobytes was considered "long"; presently few megabytes messages are considered common! Purely on this practical consideration (efficiency), it does not make sense to break messages into small packets. Furthermore, terabytes of data can be transported without error over a long distance and without the need of a repeater. This completely eliminates the reason for breaking and relaying packets unless we deliberately want to do that for some specific reason.

4. Information switching architecture

Consider a simple processing and decision process involving large blocks of raw data, a processing engine, and a final decision maker. Conventionally, the processing engine (software program running on a computer) reads in raw data one chunk at a time and processes the data to produce some partial results. At the end of the processing activity, partial results are combined and presented to a decision-making entity for final decision.

Essential to this process is the movement of raw data from its storage through the processing engine, and is then presented to relevant decision makers (that can well be human being) for further processing/decision.

Conventionally, we assume this type of processing is done within a computational element; any data movement is between its storage and the CPU and back to its storage again.

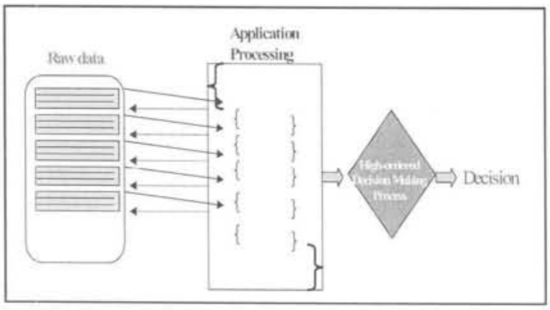


Figure 1 – A conventional data processing and decision-making process

In information switching, we view this process differently. Imagine that massive amount of raw data is flushed through a network element [11]; called **infosessor**. Information is classified and directed to relevant processing units within the network element. On the other side, partial outcomes from these information streams can be combined and presented to the decision makers.

By doing so, raw data can be intelligently sorted into relevant information streams and switched to and be processed by appropriate processing elements. All this is done on the fly as data is being transported through the **infosessor** (information switching element). Reading and processing data from its memory storage is now performed dynamically by flushing the data through an infosessor. In information switching, data is being redirected after it has been intelligently transformed into a more useful form by the infosessor. Figure 2 illustrates the architecture. Furthermore, as with any intelligent element, feedback information can be channeled back to the processing element, to the switching elements, and even the data sources to refine its processing and decision-making process.

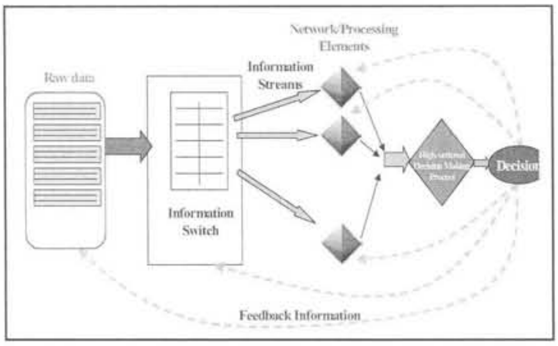


Figure 2 – Information switching and decision-making process

We can imagine it further by putting such an information switching processor (infosessor) in the network context as shown in figure 3. Information can be directed automatically to their destined destination for decision-making sub-processes. Ultimate decision outcomes can emerge from these sub-processes collectively over the network. With such architecture, intelligence is being built into the network. The situation is radically different from the current Internet where network elements are being kept simple by confining them to the task of look-up table routing. Essentially, an information switched network is expected to transport as well as transform information to useful outcomes that may constitute a final solution or part of the final solution. The significance of information switched networks can be appreciated where one encounters problems that cannot be solved by a stand-alone system individually, but requires the cooperation of multiple components over the connecting network.

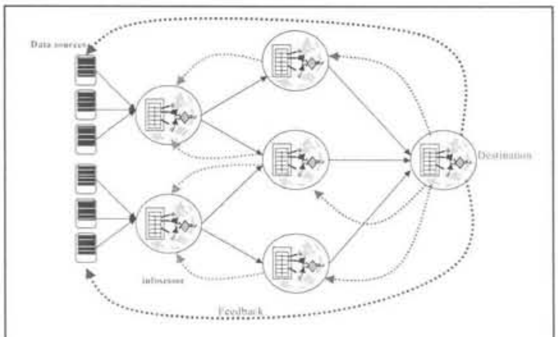


Figure 3 – Information processing in a network context

With these descriptions, an infosessor essentially consists of following components (Figure 4):

- An intelligent control component. This component houses various intelligent agents; each of them is responsible for a specific function. Some may oversee the processing of a specific information stream, some may deal with the management of the network element, and some may be responsible for the interaction with other elements within the network. In order to deal with a particular problem, the control element may take order from other agents (including human beings) to acquire an appropriate agent from some repository within the network. It may initiate and deploy the acquired agent in response to its own sensors and its reasoning capability. It may decide to construct new agents to deal with unforeseen circumstances.
- An intelligent sensory component. This component allows the infosessor to selectively filter information streams of interest, to aggregate related streams, to redirect streams to other processing elements for further processing. Reverse operations are also included. Some forms of pattern matching and information matching are necessary.
- A computation element. This element may involve a group or networked of computation processors within the network element. It is responsible for transforming information streams as directed by an intelligent agent.
- A storage element. This element may be necessary for short and long term memory. Short-term memory may be required for computation. Long-term memory may be necessary if the network is to be able to learn from mistakes and experiences.

We assume that feedback control loops between these elements are necessary to allow the network element to learn and respond adaptively to its environment.

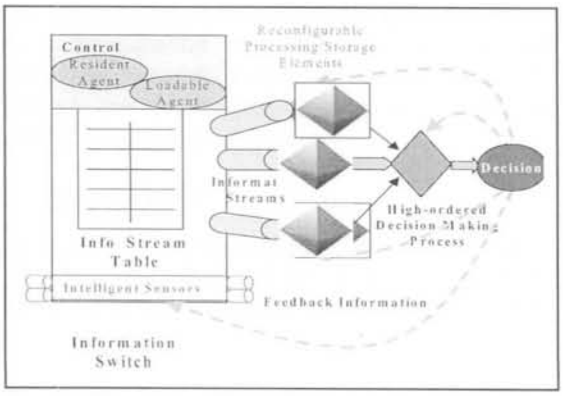


Figure 4 – An Information Switching Network Element – An Infosessor

5. Analysis and Discussion

In this section we analyse elements of our information switching architecture and provide discussion on various possible applications.

Information switching at the network edges

We envisage that the information-switching network will be built around infosessors at the edges of autonomous systems (AS) or administrative domains. There will be very little incentive for employ core routers, which function much like as dumb relays. Optical fibers with their vast bandwidth and long spans of several thousand kilometers eliminate the need for such simple relays.

Information switching on the fly

Conventional routers route packets based on their destination IP address. Conventional web-switch can perform server load balancing based on TCP segment headers. More advanced web-switches can perform layer4-layer7 filtering on the fly and redirect packets according to their applications [10]. With such advances in the design of state-of-the-art switches/routers, we envisage that an infosessor can perform deep filtering using some form of pattern matching on-line to classify/differentiate information streams and route them to their intended destination. We envisage that the differentiation and redirection can be performed on data streams based on applications, sessions, contents, or specific semantics.

Information processing

With the advances in computer and chip design technologies, a network element can integrate both gigabit switches/routers and powerful processing servers, for example, the IBM eServer BladeCenter [12]. Our infosessors can act as intelligent dispatchers as well as intelligent servers that are capable of performing sophisticated transformation to its information streams.

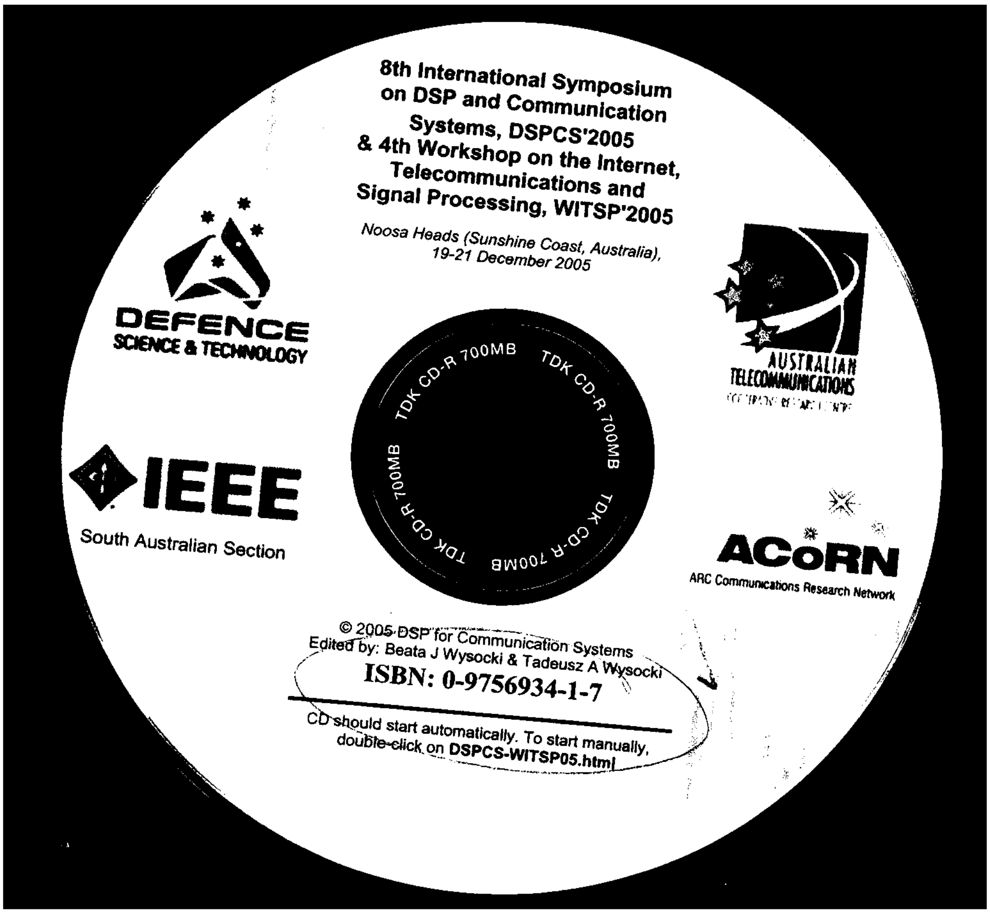
Next generation network element can incorporate plug-in FPGA components that can be tailored to specific processing need on-demand and perform required processing at hardware speed.

Furthermore, we envisage the use of active/programmable network devices that allow intelligent processing algorithms or services to be downloaded on-demand and initiated their running automatically without elaborate pre-configuration.

With such powerful network elements, there should be no limitations to the type of intelligent processing operations that can be deployed.

Network Storage capacity

It is envisaged that network elements for information switching be equipped with a large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Call for Papers

Communication Systems worldwide have provided a rapidly growing and useful range of services and are continuing to evolve using Digital Signal Processing. The 8th International Symposium on DSP and Communication Systems, DSPCS'2005, has been planned by a group of academics and professionals to examine the plans for the future and the progress that has already been made in the field of DSP and their applications to communication systems, image processing and other aspects of the modern life. The organizing committee of the symposium decided to hold the 8th Symposium on DSP and Communication Systems on the Sunshine Coast on 19-21 December 2005. A major objective of the symposium will be to pursue the progression from communication and information theory through to the implementation, evaluation and performance improvement of practical communication systems using DSP technology.

This year the Symposium will be again combined with the Workshop on the Internet, Telecommunications and Signal Processing WITSP'05. Therefore, the topics of interest range from those of the physical layer to the application layer through all aspects of the protocols and processes required for the future Internet to operate better and the applications to utilize the full potential offered by the current and the emerging networking infrastructure. In addition, we expect that, as during the previous events, there will be several papers dealing with image, video and audio processing for multimedia, and forensic applications, as well as with the security of private and corporate data.

The selected papers from the combined DSPCS'03 & WITSP'03 in Coolangatta have been published by Springer in two books: "Signal Processing for Telecommunications and Multimedia" and "Advanced Wired and Wireless Networks". It is expected that, this year, the best 20 – 30 papers, judged by the Organizing Committee, will be again published in a form of an edited volume, apart from the conference proceedings.

Previously unpublished contributions to the following technical areas, but not limited to, are solicited:

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The papers should be prepared double column, with 2.5 cm margins from all sides and use 10 point Times Roman or similar fonts. Each paper should include an abstract of up to 250 words, authors, and mailing and electronic addresses. The paper should be accompanied by a cover page including the name of the contact author with his full address including the fax number, and the technical area(s) chosen from the above and listed in the order of author's preference. Each full paper will be peer-reviewed by three independent reviewers and the authors will be notified about the acceptance via email.

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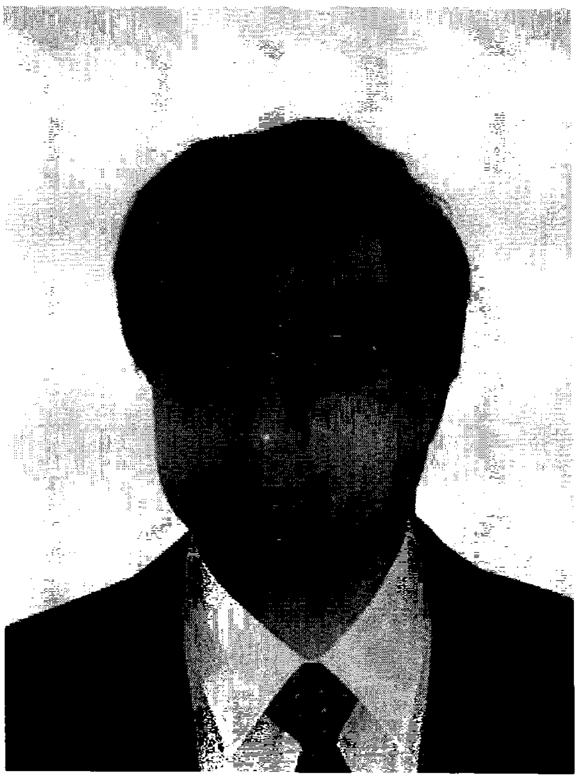

On behalf of all the members of the Organizing Commit would like to welcome you to the 8th International Symj on DSP and Communication Systems combined with the Workshop on the Internet, Telecommunications and Sigı Processing.

The Symposia on DSP and Communication systems hav established to bring together a group of researchers from industry and academia to examine plans for the future ar evaluate the progress that has already been made in the f DSP and its applications to communication systems. In 2 Organizing Committee decided to expand the scope of tl Symposium to include in our program also topics relatec networking, and combine the DSPCS'03 with the WITSI combination has been generally regarded as a very succe one, and this year, we decided to continue with this form response to the original call for papers has exceeded our expectations, with 164 full paper submissions. All subm papers have been peer reviewed, and each paper receive two but mostly three peer reviews. Based on those revie papers have been accepted, and finally, 77 included in th program - 50 for oral and 27 for poster presentations.

At this point, I wish to thank the authors who put so many efforts, first in preparing their manuscripts for submission, and then for incorporating reviewers' comments in the camera-ready papers. I extend my sin thanks to the members of the Technical Program Committee for organizing reviews for the papers, and tl reviewers for thorough reviews of the papers. I also want to thank Prof. Bahram Honary and Prof. Micha for preparing their keynote addresses "Recent Results on Construction of Structured LDPC codes" and "' Interplay of Signal Processing, Communication Technologies and RF Circuit Design with Perspectives c Future of RF and Microwave Engineering".

Finally, I would like to thank the sponsors of this event. Without their generous support, the DSPCS'05 & WITSP'05 would not materialize.

I hope that you will take pleasure in staying in Noosa Heads on the beautiful Australian Sunshine Coast, friendly atmosphere will facilitate peer-to-peer interactions and networking and be a pleasant supplemen research benefits of the Symposium.

Welcome to Noosa and enjoy the Symposium!

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