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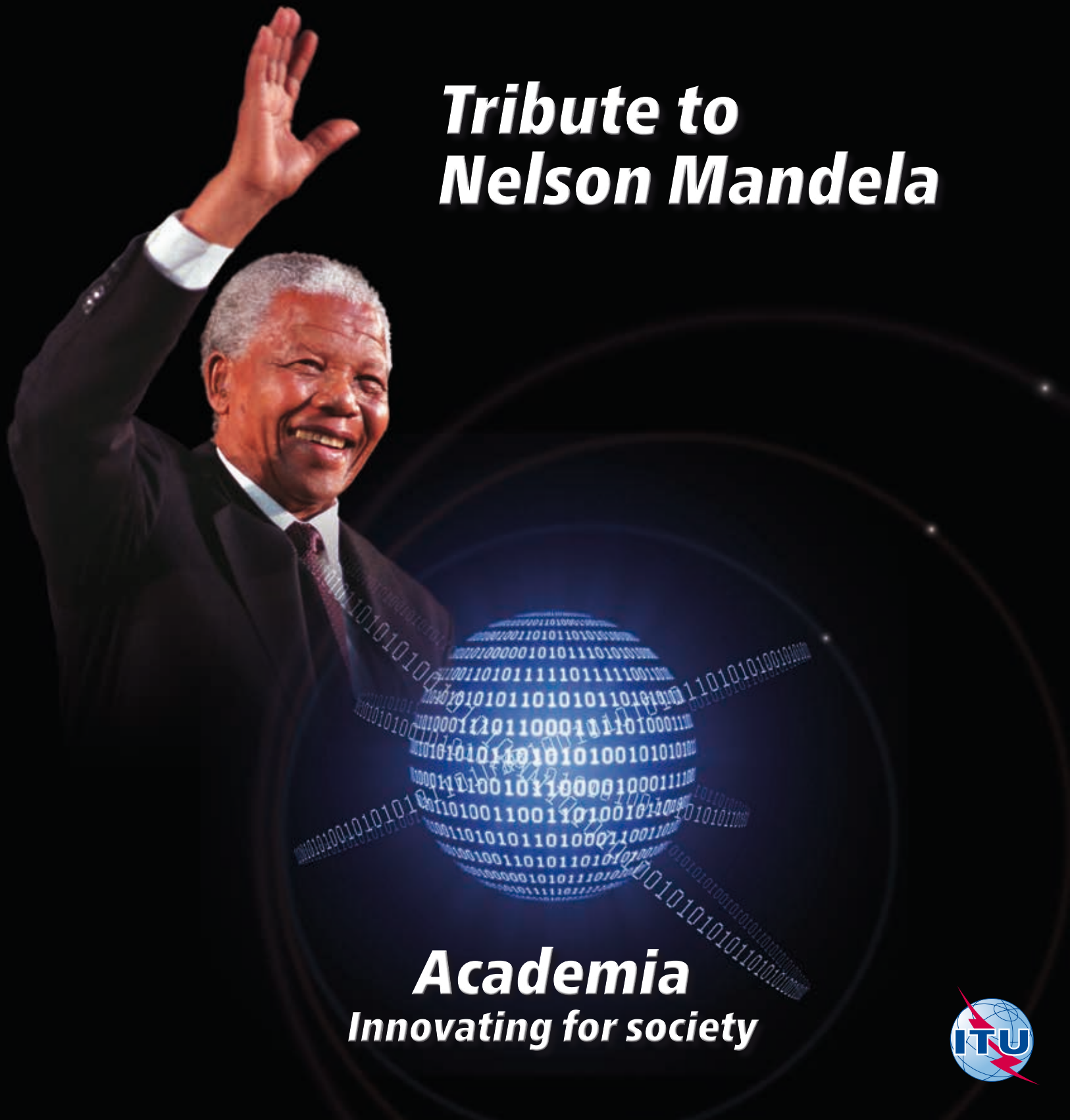

Tribute to Nelson Mandela

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Tribute to Nelson Mandela
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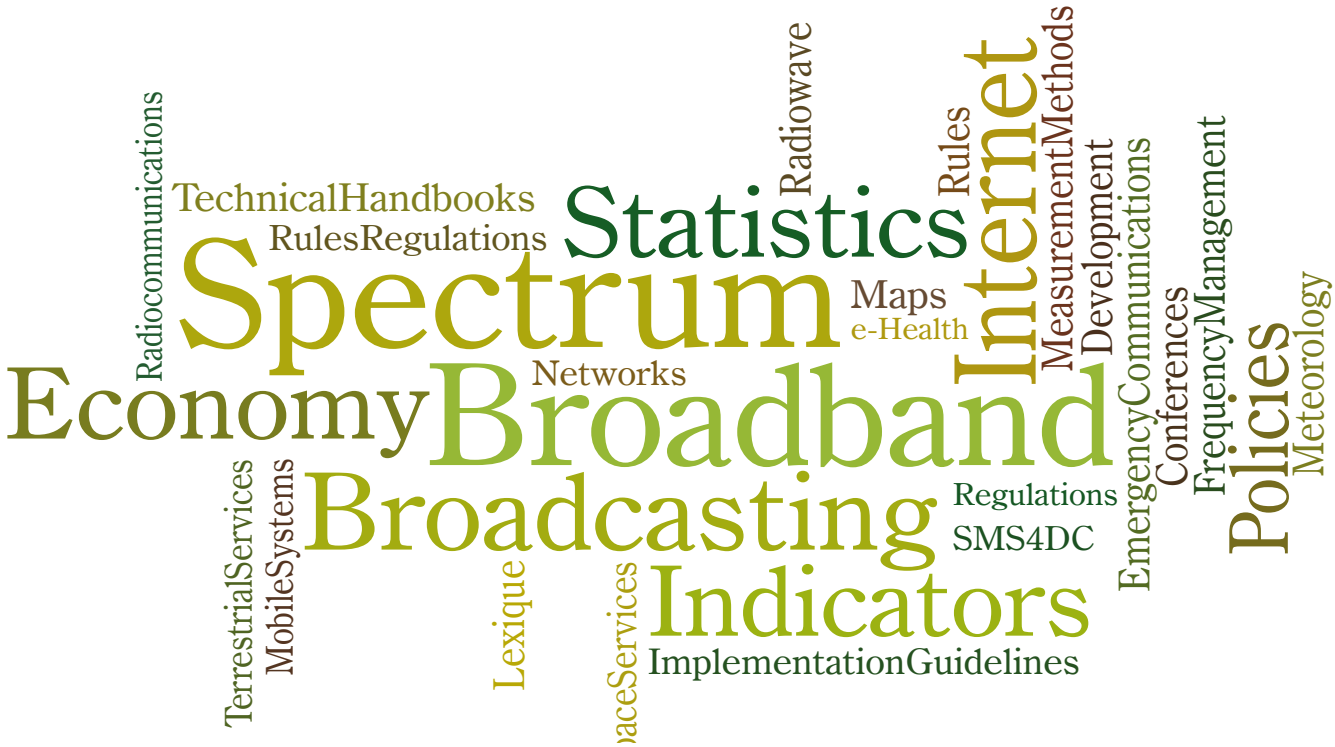

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Remembering Nelson Mandela

Dr Hamadoun I. Touré,
ITU Secretary-General


ITU/P.M. Virot

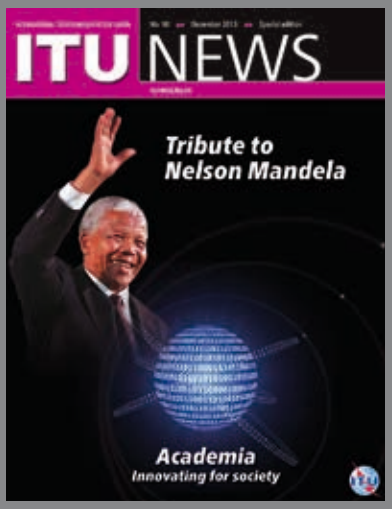
On behalf of ITU, its membership, management and staff, I extend my heartfelt condolences to the family of Nelson Mandela and to the people of South Africa. No words can express the full extent of his greatness or his legacy as one of the most transforming personalities the world has ever seen.

Despite having been incarcerated as a political prisoner for 27 years in his long fight against apartheid, he emerged with his sense of justice remarkably intact, without any trace of bitterness. Instead, he epitomized the values of trust, goodness, optimism and forgiveness, emerging as a true statesman championing the causes of truth, reconciliation and democracy.

I have personally looked up to Madiba for inspiration, as nothing in the world could ever daunt him or hold him back from his life's mission to free his compatriots from the yoke of apartheid and emerge as a world leader and statesman. His towering personality will leave a lasting impression on me, and the world will forever enjoy the legacy he has left behind in an atmosphere of peace, humility and forgiveness.

At ITU, Nelson Mandela was known for his embrace of technology as a catalyst for change and development. His speeches at several Telecom World events show this clearly (see our tribute on pages 7–13). "We need a vast expansion of our communication and information network, and ITU — as the principal driving force behind international policy, technological development, cooperation and skills transfer — is an indispensable agent in this regard", Madiba said. During ITU Telecom World 2009, he underlined that "information and communication technologies are the single most powerful tool we have for human progress" and urged participants to "support efforts to connect the world and bridge the digital divide".

ITU will remember Madiba's advice, and we shall continue to strive in our efforts to connect the world in the spirit of this great son of South Africa and of the world.



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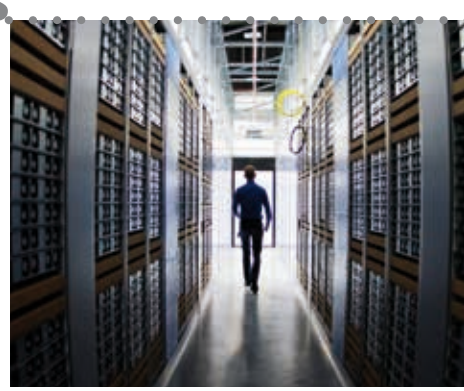

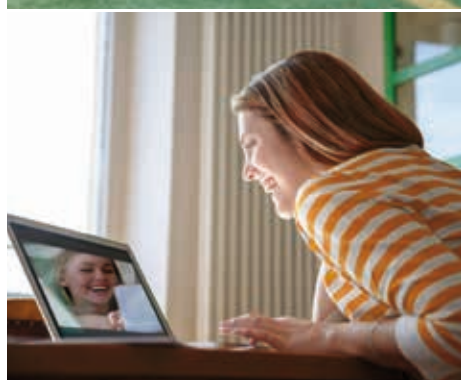

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Nelson Mandela and ITU

Humanity and human progress

The whole world mourns the passing on 5 December 2013 of Nelson Mandela, anti-apartheid leader and statesman

Nelson Rolihlahla Mandela was born on 18 July 1918 to the Thembu royal family in Transkei, South Africa. He spent the better part of his life in an epic struggle against apartheid in South Africa. In 1993, Mr Mandela was awarded the Nobel Peace Prize for his role in dismantling the shackles of apartheid. In 1994, he was elected President of South Africa, a post he held until 1999. During his tenure, he was also Secretary-General of the Non-Aligned Movement.

Madiba, as he was fondly known, will be remembered forever, not only for his accomplishments as a world statesman, but also for his deep humanity, his capacity for forgiveness, and as a champion of the downtrodden. Extending his heartfelt condolences to the bereaved family and to the Government and people of South Africa, ITU Secretary-General Dr Hamadoun I. Touré said "I have personally looked up to Madiba for inspiration, as nothing in the world could ever daunt him or hold him back from his life's mission to free his compatriots from the yoke of apartheid. His towering personality will leave a lasting impression on me, and the world will forever enjoy the legacy he has left behind in an atmosphere of peace, humility and forgiveness."

As a mark of respect to honour the passing of this great and inspirational leader and true champion of digital inclusion, the ITU flag at its headquarters in Geneva was flown at half-mast.

1995

President Mandela speaks in Geneva at TELECOM 95

As President of South Africa, Nelson Mandela was a strong supporter of ITU. Speaking on 3 October 1995 at the opening ceremony of TELECOM 95 in Geneva, he recognized ITU as a body of crucial importance for the entire African continent.

With his customary humility, President Mandela explained that South Africa was deeply honoured by the invitation to take part in the opening ceremony of TELECOM 95, the seventh World Telecommunications Forum and Exhibition — and the very first in which South Africa was participating as a full member of ITU. He saw that participation as a testament to ITU's steadfast support of his country's struggle for freedom. "On behalf of the people of South Africa, we thank you for your solidarity, and express our joy at being so warmly accepted as a full and equal partner in the all-important world of telecommunications", he said.

He also expressed his gratitude at being given a unique opportunity to present his views at TELECOM 95, which he saw as taking place at a special moment in the context of the world's potential for transition to a truly democratic information age.

Speaking not only about South Africa but also about the entire African continent, he said "We need a vast expansion of our communication and information network. ITU, as the principal driving force behind international policy, technological development, cooperation and skills transfer, is an indispensable agent in this regard."

Representing the new South African regime, he took great pleasure in announcing that, following discussions between officials of ITU and the South African government, "we have formally invited the Union to hold its next Africa region Telecom Exhibition and Forum in 1998 in South Africa. We would be happy and proud to host this prestigious event."

Mr Mandela went on to underline the importance of communication and access to information for human beings around the world, and stressed the need to work towards eliminating the divide between information-rich and information-poor countries.

"The value of information and communication is felt with particular force when, as happened in South Africa for so many years, their denial is made an instrument of repression. Such measures, however, ultimately evoke inventive and innovative ways of circumventing the restrictions. For example, as prisoners on Robben Island, when we were deprived of newspapers we searched the refuse bins for the discarded sheets of newspapers which warders had used to wrap their sandwiches. We communicated with prisoners in other sections by gathering matchboxes thrown away by warders, concealing messages in false bottoms in the boxes and leaving them for other prisoners to find. We communicated with the outside world by smuggling messages in the clothing of released prisoners. Not even the most repressive regime can stop human beings from finding ways of communicating and obtaining access to information", declared Mr Mandela.

He saw the inexorable force for communication and access to information as applying in equal measure to the information revolution sweeping the globe. "No one can roll it back. It has the potential to open


Getty Images

communications across all geographical and cultural divides", he said.

President Mandela nevertheless identified one gulf that would not be easily bridged — the division between the information rich and the information poor. "Justice and equity demand that we find ways of overcoming it", he asserted. He saw clearly that, if more than half the world was denied access to the means of communication, then the people of developing countries would not be fully part of the modern world. Speaking as a visionary at the end of the 20th century, he foresaw that in the 21st century the capacity to communicate would almost certainly be a key human right.

President Mandela knew that eliminating the distinction between information rich and information poor countries was also critical to eliminating economic and other inequalities between North and South, and to improving the quality of life of all humanity.

He was aware that converging developments in the fields of information and communications offered immense potential to make real progress in that direction. "The pace at which the price of communications and information systems has fallen has also undermined the previously rigid link between a nation's wealth and its information richness. There is an unprecedented window of opportunity", he said.

Those were some of the challenges regarding the globalization of telecommunications and the information revolution which were of concern to South Africa and many developing countries, he explained. "If we cannot ensure that this global revolution creates a worldwide information society in which everyone has a stake and can play a part, then it will not have been a revolution at all", he stated.

Heading towards the 21st century, he identified one of the highest priorities as being the development of a global information society based on justice, freedom and democracy. To that end, he listed a set of principles designed to enable the full participation of both the developed countries and developing countries in building a

global information society. Those principles envisaged: global universal service in telephony and global universal access to the information superhighway; expansion of the global information infrastructure, based on partnership and rules of fair competition and regulation, at both national and international level; gearing the information revolution towards enhancing global citizenship and global economic prosperity; respect for a diversity of paths towards the achievement of national information societies; internationally coordinated evolution of policy for the development of an equitable global information society to ensure the sharing of information and resources; and education of young people in the skills needed for living in an information society.

In concluding his address to TELECOM 95, President Mandela emphasized the importance of young people to the information revolution. "Many of us here today have spent much of our lives without access to telecommunications or information services, and many of us will not live to see the flowering of the information age. But our children will. They are our greatest asset. And it is our responsibility to give them the skills and insight to build the information societies of the future. The young people of the world must be empowered to participate in the building of the information age. They must become the citizens of the global information society. And we must create the best conditions for their participation", he said.

Pekka Tarjanne, Secretary-General of ITU at the time, knew full well that, while the African continent needed the professional telecommunications support that ITU could provide, ITU itself and its Telecom activities would be bathed in the reflected glory of a radiant son of Africa. "We are absolutely delighted that President Mandela, who is such an inspiring figure to the world because of his lifetime of struggle against injustice, should feel that Telecom is an important enough event to fit into his very demanding schedule," said Dr Tarjanne.

1998

President Mandela speaks in Johannesburg at Africa Telecom

ITU accepted the formal invitation made by President Mandela and subsequently held the regional ITU Africa Telecom event in Johannesburg. President Mandela considered it a privilege to welcome Telecom participants to his country. "It allows our nation to take its place in a forum of critical importance to Africa's future. And it is an opportunity to give practical expression to our desire to be fully part of the rebirth of our continent," he said. "As the information revolution gathers yet more pace and strikes deeper roots, it is already redefining our understanding of the world. Indeed, the speed of technological innovation could bring the ideal of the global village


AFP

sooner than we thought possible. For the developing world, this brings both opportunity and challenge."

President Mandela saw that the world was rightly attempting to harness the immense potential of telecommunications, but he pointed out that the attempt was being made in the context of stark disparities between the industrialized and developing worlds, and warned that those imbalances could easily reproduce and entrench themselves. He said that "although much is being done in attempting to bridge the gap between the information haves and the information have-nots, the task remains daunting. Indeed it is sobering to consider the information revolution from the point of view of global development and its capacity to help raise the quality of life. We have to say that our collective vision is in danger of failing where it counts most, namely the goal of universal access to basic telecommunications services."

He acknowledged that the targets set by developing countries to bring all humanity within easy reach of a telephone would not be achieved on the African continent as the new millennium dawned. He then posed the question of how— in partnership with counterparts in the developed countries — to bridge the gap so that Africa could march in unison with the rest of humanity into the 21st century.

In answer to the question of how to avoid drifting to the margins of the emerging global information society, he set out a new vision based on the recognition that the full benefits of the telecommunications revolution would be reaped only if certain fundamental principles were respected. Foremost among those principles was the right of universal access to telecommunications, a goal

that new technologies made achievable. That was consistent both with a principled commitment to equity and with the role of telecommunications infrastructure in socio-economic development. "In addition, we require a massive investment in human resources. Education and training for specialists, students and business people are key elements in preparing our countries for the information society. And we need to create a telecommunications infrastructure suited to a world in which rapid change in information technology is reshaping the way business is done. To do this we have to overcome the most pressing challenge facing Africa in this sector, namely limited finance for investment in infrastructure. A restructuring of the telecommunication sector in order to maximize the utilization of scarce resources will help in this regard. But in particular we need to mobilize our collective wisdom to attract greater investment in the expansion of telecommunication networks and for human resources development. Africa remains a huge untapped market for telecommunications and information technologies. Like other emerging markets, it presents huge opportunities for investors", he said.

In his view, the investment needs of the rapidly expanding telecommunications and information technologies industry could not be met by the public sector alone. Rather, he considered that they could be met only through partnerships between the public and private sectors. Such partnerships would promote a climate for sustainable investment in infrastructure that would guarantee good returns and at the same time help close the information gap.

If these partnerships were to have the maximum effect in promoting the goals that he had set out, then they would need to have some coordinated vehicle like a dedicated African Telecommunications Development Fund. Such a fund would finance the infrastructure projects required to extend telephony to every village in Africa and would certainly put the continent on the map of the global information society.

He exhorted the international telecommunication community gathered together at Africa Telecom 1998 to serve future generations of Africa's children well. "Let us lay the basis for a partnership to take Africa into the information society of the 21st century: a partnership that should help turn millions of Africa's illiterate children into engineers, doctors, scientists and teachers; a partnership that should make access to basic health services through communication technology a reality for every African; a partnership that should give millions of Africans working the land access to global markets; in short a partnership that should help fuel the African Renaissance", he said, concluding that "the freedom you helped us achieve has brought South Africa the opportunity to address the basic needs of our people through reconstruction and development."

2009

Madiba speaks via video to ITU Telecom World 2009

As late as 2009, Nelson Mandela continued to support the work of ITU. Speaking via video link at the opening ceremony of ITU Telecom World 2009, he underlined that "information and communication technologies are the single most powerful tool we have for human progress" and urged participants to "support efforts to connect the world and bridge the digital divide".

That was Nelson Mandela — a truly remarkable and unforgettable man.

ITU Secretary-General Dr Hamadoun I. Touré speaking at the opening ceremony of ITU Telecom World 2009

ITU / F. Rouzioux

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Role of Academia in ITU and ICT

Professor Toshio Obi

ITU Special Envoy for Academia, and President of the International Academy of Chief Information Officers

This special edition of ITU News presents 12 articles by authors from ITU's "Academia" category of membership. The original research papers submitted by the authors were reviewed by an advisory editorial committee, prior to being edited for publication in this issue.

Academia participates in ITU

On 14 January 2011, ITU welcomed the first 12 academic institutions admitted to participate as such in the activities of its three Sectors: the Telecommunication Standardization Sector (ITU–T), the Telecommunication Development Sector (ITU–D), and the Radiocommunication Sector (ITU–R). At the ceremony, ITU Secretary-General Hamadoun I. Touré welcomed me, along with Professor David Mellor of the United Kingdom Telecommunications Academy (UKTA) as ITU's Special Envoys for Academia. Since then, we have been working to fulfil this mission in every corner of the world.

ITU membership for academia is enabled under Resolution 169 (Guadalajara, 2010) on "Admission of academia, universities and their associated research establishments to participate in ITU's work". The Resolution encourages the involvement of universities and their associated research establishments in the work of ITU. Representing a major step forward in broadening ITU's membership base, the Resolution specifically provides for reduced membership costs for academic institutions. Subject to an initial four-year trial period, it allows academic institutions to participate in the work of any or all three Sectors until the next Plenipotentiary Conference, to be held in 2014. Academic institutions wishing to join ITU Sectors must be supported by the Member State to which they belong.

On one hand, considering that the academic community works on state-of-the-art developments in information and communication technologies (ICT) within ITU's field of competence, the scientific contributions of academia is likely to far outweigh the financial incentives offered to encourage their participation. On the other hand,

participating in the work of the ITU Sectors gives academic and research institutions the opportunity to exchange views, knowledge and experiences with a multiplicity of actors from both the developed and developing worlds. There are opportunities for academic institutions to develop mutually beneficial partnerships with manufacturers, operators and public authorities from across ITU's 193 Member States. Academic institutions have the chance to play an active part in the ongoing activities of ITU's Sectors and to influence emerging new technologies and standards. Participating in ITU meetings and workshops also brings academia face to face with wider challenges in the ICT public policy and regulatory arena, beyond purely technical concerns.

Academia membership grows

As at 12 December 2013, a total of 66 Academia participants from 39 countries had joined the Union. In terms of Sector-wise affiliation (bearing in mind that some institutions have joined more than one Sector), ITU–T has 46, ITU–D has 16, and ITU–R has 15 Academia participants. By country, Japan has 5 Academia members, China and India each have 4, the United States, Italy and Sudan each have 3, and Germany, Argentina, Algeria, Brazil, Ghana, Malaysia, Mexico, Switzerland and Tunisia each have 2, with 26 other countries each having one Academia participant.

Benefits of participating in ITU

I conducted a survey among all ITU Academia to elicit comments on their experience of participating in the Union's work. The most interesting replies from the 22 academic members that responded in August 2013 to the brief questionnaire (five questions) concern how they evaluate the benefits of their membership of ITU. Here are their answers.

1. Membership of ITU enables us to strengthen our academic research by closely following standardization efforts in the industry.
2. The main benefit is the ability to get information well ahead of the deadline for joining different programmes that are of interest to us. Being a member opens up opportunities and gives us access to materials.
3. The most prominent benefits are access to internal ITU documents via our TIES account, access to the e-mail lists of the relevant study groups and telecommunication companies, and the opportunity for networking at physical meetings.
4. The greatest benefit for us is access to draft documents prior to publication and working documents. We do not often participate in the face-to-face meetings because of the cost, but the ability to do so when necessary is important to us.
5. The benefits are access to ITU documents and the possibility of attending meetings.
6. We are able to obtain valuable information on ICT activities and achievements.
7. The main benefits are access to TIES restricted documents and participation in the spectrum management training programme. We are beginning to understand the functioning of ITU and expect most benefits to come in the near future.
8. The main benefit is access to standards and documents. The possibility of participating in or hosting workshops is also a benefit.
9. I have not seen any benefits. Maybe we need clearer guidelines from ITU on what our roles are and what we can participate in. Also, going to Geneva for events is very expensive for developing nations. There should be better alternatives, such as good quality videoconferencing provided by ITU.
10. ITU regularly informs us about all the activities that it organizes. We are invited to participate in these events, and we receive information about the decisions that have been taken and the different reports that are available.
11. The benefits are that we can actively participate in the telecommunication standardization process or in other ITU-related matters (such as the debate on standard time). The spirit of

independence in conducting research and education is very important for our university; without ITU membership, we would have to bow to the concepts and plans set by the telecommunication industry or the government.

12. ITU is a prestigious and well–known organization. Academia membership gives us the chance to be in touch with other academic institutions, and it also provides an opportunity to get to know and contact companies that commercialize ICT products and services. As a university with both academic and industry-related goals, it is of paramount importance for us to be part of the worldwide ITU community. Moreover, ITU journals keep us constantly updated about conferences, meetings and all the news in the ICT world. For these reasons, we have decided to maintain our membership and to continue allocating funds to cover the required payments. We will try to be more active and take greater advantage of the benefits of ITU Academia membership.
13. The greatest benefits are interacting with the ITU membership, as well as contributing to setting new standards.
14. Access to study group work in all the ITU Sectors is essential for our strategic development planning of research projects and education. Another benefit is the opportunity to make contact with ITU Members States — especially developing countries — for the purpose of disseminating our projects and educational programmes. A specific benefit of membership is that it opens up an opportunity for our students to embark on professional careers in ITU.
15. Membership of ITU has helped us market our postgraduate programme, especially our Master of Law course in information technology and telecommunications, to other ITU members.
16. An important benefit is having the possibility of accessing the ITU research database, because of its relevance to the academic programmes that we offer. This is of particular significance for us because we are the only university in the country that offers a course in telecommunications engineering.
17. Benefits include participating in study groups and standards development, connecting with other ITU members,

and promoting the role of chief information officer.

18. The main benefits are exposure to recent standards and state-of-the-art technologies, and the possibility of participating in debates on matters of current concern.
19. Major benefits are being able to get the latest information and materials on hot topics, and having an opportunity to express our opinions on those topics.
20. Membership opens up possibilities for initiating, participating in and carrying out large-scale projects to benefit the international community. It offers a good way of introducing current technical standardization trends into academic research, as well as proposing research innovations coming from Academia to be introduced into technical standards specifications, while receiving feedback from working group discussions about the viability of deploying academic innovations.
21. We appreciate the benefits of getting the latest information and material on important topics and being able to express our opinions on them.
22. In the ICT community, the tripartite productive partnership among government, industry and academia is the most significant engine for innovative progress.

Another question in the survey asked about the kind of ITU activities in which academia participated. The answers indicate participation in various ITU events in all three Sectors, such as working groups, study groups, seminars, workshops, regional conferences, Kaleidoscope, Centres of Excellence, world radiocommunication conferences and ad hoc events.

Based upon the outcome of this survey, I decided to organize the first academia workshop in Bangkok on 20–21 November 2013, to coincide with ITU Telecom World, to discuss the future of academia membership, as well as the associated benefits and problems. This workshop will give important feedback to ITU.

Recommendations for ITU

We academics have appreciated the easy access to all ITU's statistical data, as well as to the reports of study groups. I am sure that this thirst for information will increase in the future, because academics see it as one of the main benefits that their membership of ITU provides. In counterpoint, there are lots of opportunities for academia to contribute to ITU's activities.

I hope ITU might consider engaging a consortium of academic members — including the top ICT universities — to study the challenges and opportunities that arise in creating the future dimensions of the information society. Further, I might recommend that ITU academic members undertake activities to strengthen the information and communication technology sector, and foster ICT innovation as well as research and development. Such activities would include academics taking on consulting and advisory roles, perhaps through a centre of excellence in ICT community development.

To expedite the enrolment of academia in ITU, we need financial support for academic institutions, especially those in developing countries, to help cover their ITU annual membership costs and travel expenses.

My idea is that ITU's future programmes for academia might include such fundamental aspects as academic publication, offering opportunities to participate in workshops and conferences, and recruiting academics to play an advisory role or to evaluate current ITU activities. Academic institutions could engage in public-private partnerships for research and development, working in the areas of ICT innovation and emerging technologies.

A series of recommendations by academia emerged from the survey. Respondents think that academia should play a dynamic role in ITU activities, for example by providing input in defining the priorities for the Union's new strategic plan (2015–2019), by participating in regional activities, and by forming a neutral body (composed of an international team of academia members) that could evaluate and

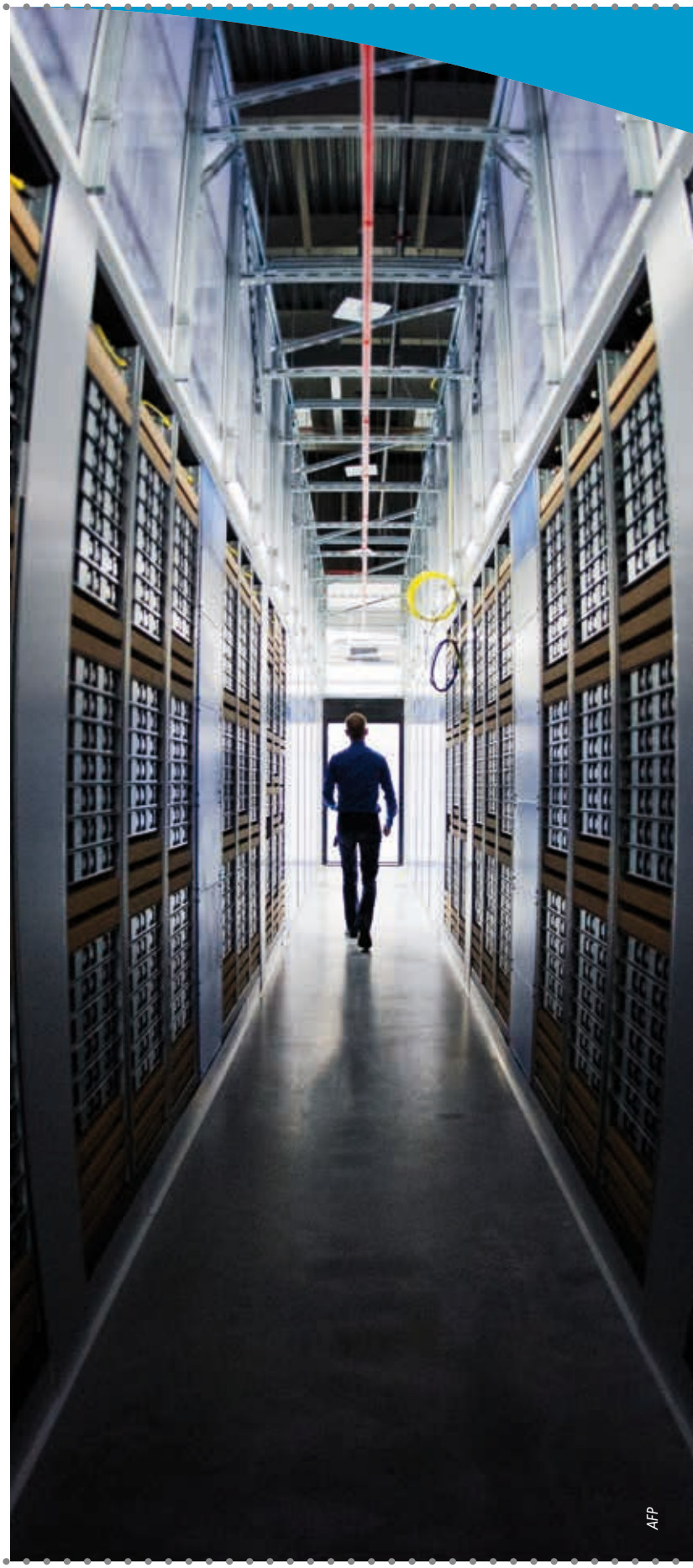
monitor major ICT activities and government ICT strategies and plans. Academic institutions could also support ITU's continuing work on ICT with international academic associations such as the Institute of Electrical and Electronics Engineers (IEEE) and the International Academy of Chief Information Officers.

Academia members call for more systematic collaboration between academia and industry groups on research and development. They also suggest that ITU should publish a semi-annual journal for academics — with contributions by professors and researchers from academia — on major advances in science and technology related to ICT.

Academia members would like to participate in workshops, seminars and conferences on priority areas including cybersecurity, emerging technologies such as cloud computing and mobile broadband, ICT for development, digital inclusion and the use of ICT in disaster reduction. They recommend that ITU should organize global meetings or workshops for Academia as platforms for the exchange of learning about best practice, and as forums for networking opportunities.

Several recommendations concern boosting participation by academia, and specifically what ITU could do to support its academic members. In particular, respondents want ITU to provide travel grants for Academia members in developing countries to enable them to attend events. One suggestion is to use virtual communication facilities such as teleconferencing to make participation possible for academic members that cannot afford to attend events physically. Another idea is to promote workshops for academia in low-income countries.

One respondent suggests that participating in ITU should give Academia members an opportunity to promote their institutions (universities or research institutes) via an ITU academia portal that should be open to the public. Another related idea is that ITU should ask member governments to promote ITU academic membership and provide relevant support for universities that apply. Similarly, ITU should ask both global and local business groups to encourage the universities in their communities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by providing grants to academic institutions applying for ITU membership.

In my view, Academia membership in ITU is far from reaching its full potential. We still have to fill a lot of gaps, including the availability of financing and the extension of membership to the top universities with ICT faculties in each country. If the number of Academia can grow to about 200, then this category of membership will be able to make a range of significant commitments to ITU activities.

ITU–T is active in the field of academia events, for example through its Kaleidoscope workshop. But individual academic participation — without ITU membership and payment of the associated fee — is not sustainable because of the lack of solid funding, which requires prompt solution.

Universities are autonomous and their research facilities are independent. Governments as well as industry see the benefit of using academic facilities, which are managed in a manner that differs from the way that both business and government are managed. The Union could similarly take advantage of the resources of academic communities.

As an intergovernmental organization within the United Nations family, ITU is the institutional home of ICT for the world community. I sincerely hope that the concerned parties will support active collaboration between ITU and academia, which will be the key for pioneering innovation in ICT in the future.

About the author

***Toshio Obi** is the Director of the Institute of e-Government at Waseda University, Japan, and a professor at the Institute. He obtained his PhD in information and communication technologies from Waseda University and then worked for the United Nations Development Programme. He later became a senior researcher at Columbia University in New York, United States. He chaired the ITU Asia-Pacific Region Centre of Excellence Management Committee from 1995 to 2007, and the ITU TELECOM Programme Advisory Committee from 2007 to 2011. He currently chairs the United Nations Educational, Scientific and Cultural Organization (UNESCO) University Twinning and Networking Scheme (UNITWIN) on disaster preparedness. He is co-chair of the Committee on Information, Communications and Computer Policy (ICCP) of the Organisation for Economic Co-operation and Development (OECD), leading its work on the use of information and communication technologies to support the elderly.*
Professor Obi is the Director of the APEC e-Government Research Center at Waseda University and a member of the expert group set up by the Division for Social Policy and Development of the United Nations Department of Economic and Social Affairs to discuss e-participation.

Telecommunications for pandemics and nuclear disasters

Isao Nakajima

Vice-Rapporteur on e-Health for ITU Telecommunication Development Sector (ITU–D) Study Group 2 and Professor, Department of Emergency Medicine and Critical Care, Tokai University, Tokyo, Japan

In this article, I describe two entirely different cases of the use of telecommunications to protect human health and safety: first in giving early warning of the spread of avian influenza; and second in sending emergency alerts after the Fukushima nuclear disaster.

ICT to help prevent avian influenza

Outbreaks of avian influenza — caused by widespread transmission between birds, animals and humans — are believed to have periodically inflicted a grave human toll since ancient times.

The genes of the avian influenza virus mutate rapidly, creating an obstacle to preventive strategies by hindering prompt identification of antibodies required for preparation of the antigen and vaccine. Some researchers predict that avian influenza may result in death rates of 60 per cent in developing countries and 10 per cent in developed countries — alarmingly high rates compared to severe acute respiratory syndrome (SARS), which recorded a death rate of 4 per cent.

The influenza viruses that cause epidemics today were once generally fatal to humans, but their pathogenicity has decreased over time. Generally, mutations occurring in viruses found in carrier birds (swans, geese, ducks and so on) during bird-to-bird transmission increase pathogenicity, producing new strains of avian influenza. The body temperature of the birds involved is considered to be one of the parameters affecting this process. The consensus view among experts is that it is simply a matter of time until bird-to-human transmission occurs from migratory birds carrying high-pathogenicity viruses.

In nature, deaths among wild birds go unnoticed by human observation, and a major cause of such deaths may be the influenza virus. Even where infection with pathogenic influenza virus is low, the living bird's body reacts by losing mass.

Avian influenza appeal

A Statement of Appeal on an Integrated Information and Communications Network for Avian Influenza (commonly known as the Statement of Appeal on Avian Influenza) was discussed and adopted at ITU–D Study Group 2 Rapporteur's Meeting for Telemedicine. The meeting, hosted by Japan's Ministry of Internal Affairs and Communications, was held in Tokyo on

3–4 July 2008. The meeting recommended the actions listed below — related to the application of telecommunication technologies — to prevent and contain avian influenza.

Principle of information disclosure: Any governments and individuals involved must disclose information on avian influenza infection immediately upon its discovery.

Tracking technologies: We ask ITU and associated governments and corporations to seek to develop technologies to track bird migrations, including nano telemetric devices, radio-frequency identification (RFID), data collection satellite systems, wireless radio system and so forth.

Securing radio frequencies: The following tasks will be assigned during the implementation of tracking technologies: ITU Radiocommunication Sector (ITU–R) — priority utilization of frequency bands.

Integrated information network: ITU will work with the World Health Organization (WHO) to create the Information and Communications Network for Avian Influenza, disseminating telecommunication technologies to prevent and contain outbreaks to various nations.

International organizations: The relevant international organizations should work together with ITU to integrate various advanced ICT networks to prevent avian influenza outbreaks and to call on individual governments for participation in the network.

Establishment of human resource training programmes: International organizations and governmental aid agencies are encouraged to provide educational materials, knowledge and programmes to train specialists in related fields (telemedicine, especially for avian influenza tracking, information networks, and so on) in developing countries.

Tracking and monitoring birds using telecommunication technologies offers a way of predicting outbreaks of avian influenza early enough to take protective measures. The existing technology (the ARGOS system) that is currently being used in migratory bird flyway surveys requires a heavy ground station unit and the device cannot be attached to small migratory birds because of its high battery consumption.

Tokai University, in collaboration with the Yamashina Institute for Ornithology, is developing a compact size terminal that emits a wireless packet signal with a 10-milliwatt output using the 2.4 GHz Industrial, Scientific, and Medical (ISM) frequency band. The terminal can be used to store and forward data — such as heart rate, respiratory pattern, wingstroke frequency and body movement, as well as location — collected via three-dimensional acceleration sensors and the Global Positioning System (GPS). In the future, we expect to develop a power generation method using electromagnetic induction for a subcutaneous device that is protected from the sun to detect antigen-antibody reactions. By mapping this information, we will be able to chart the spread of avian influenza (see photo of pheasant).

Roles and challenges of communication in the accident at Tokyo Electric Power Company's Fukushima No. 1 nuclear power plant

Distribution of potassium iodide tablets

Following the accident at Tokyo Electric Power Company's Fukushima No. 1 nuclear power plant, communication systems failed to maintain contact with the population affected.

Because of electricity stoppage and physical damage of circuits, not enough communication lines were kept open between local governments and central government. This made it difficult to ensure that all residents of Fukushima were provided with potassium iodide to counteract the effects of radiation.

I was involved in the field of disaster communications and emergency medical care as guest research scientist at the Fukushima Nuclear Accident Independent Investigation Commission established by the National Diet of Japan, and I was a reviewer of the Commission's report. I also investigated and reported on disaster communications after the Fukushima nuclear power plant accident. I suspect that local

Flight test using a wingstroke-based back-mounted electromagnetic induction power generator and data logger (on a Japanese pheasant)

governments were hesitant to distribute potassium iodide tablets to residents because of the potential side effects.

Hazard alert

Data from the System for Prediction of Environmental Emergency Dose Information (SPEEDI) made publicly available on 24 March 2011 indicated a wide region in which cumulative radiation exposure doses were dangerously high. This area encompasses Iitate-mura, Kawamata-machi and Minami Soma City. As of 15 March 2011, calculations based on radioactive substance diffusion forecasts by W-SPEEDI (the worldwide version of SPEEDI) indicated a significant discharge of radioactive materials following the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant: 10 trillion becquerels per hour, according to estimates based on the amounts of radioactive iodine measured at Chiba City. This information was never disclosed as a result of inadequate coordination.

Emergency communications in Fukushima

Between the Government of Japan and local governments, there are three independent nationwide emergency communication systems: J-ALERT (warning system for missile launch, terrorism and natural disaster); LASCAOM (local government V-SAT network in the Ku-band); and the municipal radiocommunication network (via domestic satellite and VHF radio) for disaster management. Separately from these three systems, there is a two-way video conferencing system via Inmarsat satellite, which is applied between the Ministry of Economy, Trade and Industry, electrical power companies, and each local government of a community where a nuclear power plant is located.

The accident at the Fukushima Nuclear Power Plant caused a hydrogen explosion. Immediately after that explosion, the Government issued an evacuation directive to the heads of local government but the communication did not reach them. As

a result, many Fukushima citizens failed to get out in time and were unable to avoid radiation exposure.

Given the disaster communication networks listed above, the question arises of why the evacuation order and the evacuation advisory issued by the Government did not reach the heads of the local government. The independent wireless VHF police radio network was the only operational network in Fukushima after the earthquake of March 2011. The heads of local government claim that the evacuation directive should have been transmitted via police VHF radio.

The report by the National Diet of Japan's Fukushima Nuclear Accident Independent Investigation Commission concluded that extensive damage had occurred because "Evacuation instructions were not appropriately transmitted to the public".

Because of the earthquake, the power supply from Tohoku Electric was cut at the disaster site. As a result, mobile phone and fibre-optic networks were disrupted, causing a failure to transmit sufficient information. Potassium iodide tablets were not distributed and administered. Hospital patients and the elderly were transported by bus over long distances, resulting in loss of human lives. The Fukushima Nuclear Accident Independent Investigation Commission believes that smooth transmission of information would have avoided unnecessary exposure of residents to danger. Communication — or, rather, the lack of communication — played a crucial role in the Fukushima nuclear accident.

Lessons learned from the Fukushima disaster

Several lessons have been learned from the disaster. To avoid failures in communication like those experienced during and after the Fukushima disaster, we should:

- Establish an emergency phone number (119) as a universal service obligation.
- Establish a public phone line as a universal service obligation.
- Establish an emergency announcement channel, with "Get out of the area!" as a final evacuation call.
- Establish a double or triple SPEEDI line as a radiation measurement system.
- Develop an emergency radiocommunication network.

For all this to happen, we must have full cooperation of the public and private sectors to allow emergency access to stationary orbit satellites and high orbit quasi-zenith satellites, and to prepare hundreds of kilometres of optical fibre (battlefield standard) to be temporarily installed by helicopter in the event of an emergency.

About the author

Professor Isao Nakajima received his MD degree in 1987 from Tokai University, a PhD (Medicine) in 1987, and a PhD (Applied Informatics) in 2009 from the University of Hyogo Graduate School of Applied Informatics, Japan. He has studied telemedicine for more than 30 years, and he led the Asia Pacific Medical Network, which used the Engineering Test Satellite V (ETS-V) as part of the PARTARS project. Professor Nakajima has served as consultant for the World Health Organization, the World Bank and the Japan Aerospace Exploration Agency.

Digital television networks over DVB-T2

Example of an interactive ecological game in Colombia

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The development and deployment of interactive applications is an important aspect of the adoption of digital television in Colombia. It opens up possibilities not just for entertainment and commercial purposes, but also for education, political participation, cultural inclusion and other aspects of well-being.

For decades, broadcast television has been the primary source of information and entertainment for most people in Colombia. According to a recent quality of life survey, 91 per cent of Colombian homes possess one or more colour television devices. Television can reach remote areas, some of them important in terms of bio-diversity where the inhabitants tend to be unaware of the need to preserve valuable ecosystems.

This article outlines the process of creating an ecological game as an interactive application for three different platforms under the adopted DVB-T2 standard. The point of this serious game is to impart knowledge over public or private television channels — a method called t-learning.

Serious games and digital television

With analogue shutdown scheduled for 2019, the steady deployment of DVB-T2 networks is making it possible to offer viewers a new range of educational and interactive contents, to complement more formal academic education. Because

television is customarily seen as a source of entertainment, we believe that educational goals can be more effectively achieved by presenting content in the form of games.

Serious or applied games — with an educational purpose that goes beyond pure entertainment — are generally designed to simulate real events, in order to train or familiarize the player with a particular process or situation. Games require user interaction. This is a particularly important feature of educational games because it has been shown that the most successful learning experiences come from practice and direct involvement with the topic being studied.

Digital television is the answer. By allowing the development of rich interactive multimedia applications, and the possibility of using a return channel to send user-generated input, modern television standards are finally bringing powerful educational tools into the homes of millions of people who currently have very limited access to other means of communication, such as the Internet.

Interactivity for digital television

There are basically two types of television interaction, namely one-way and two-way. The former relies on information about the client, such as location and time of the day, in order to provide relevant content, for example weather reports or sports statistics. The latter requires a return channel, in order to be able to react to input from users, for example in surveys, social networking, or video-on-demand.

Colombia could use both types of interaction. Because 84 per cent of homes do not have in-house access to the Internet, one-way interaction is the architecture of choice for applications. However, mobile Internet access is growing at an accelerating rate: by 15.3 per cent in just the first trimester of 2013. This opens up the possibility of a massive market for Internet-aware television interactive applications. Either through the progressive adoption of devices enabled to carry DVB-T2 lite (the mobile version of DVB-T2) or through the development of "second screen" solutions, two-way interactivity is the future of digital television in Colombia.

Development of interactive applications

A number of technologies have been proposed in recent years to implement interactivity in digital television. Currently, just two stand out as viable choices for the Colombian DVB-T2 standard: the multimedia home platform; and hybrid broadcast broadband television.

The multimedia home platform is a middleware addition that allows the execution of Java applications on top of the broadcast signal. These applications are self-contained and easily deployed on a compliant television or set-top box. The standard is well-established, with a large developer community and extended manufacturer support. On the downside, the development of intuitive and esthetically pleasing user interfaces can be a challenge.

Hybrid broadcast broadband television is an initiative of a large consortium of communications and consumer electronics players led by the most well-known technology organizations in the world. The main goal is to offer a standardized way of developing hybrid (broadcast and broadband) services that could take advantage of the growing ubiquity of Internet access to pull content online, after the user has initiated the interaction while watching broadcast content.

Applications are developed in CE-HTML, a subset of XHTML original specification, with a javascript application programming interface to handle user interaction and resource access. This technology offers a more modern approach to the development of interactive applications, but its adoption in developing countries is likely to be slow because Internet access is virtually mandatory and current manufacturer support is limited to proprietary middleware.

While the multimedia home platform is falling from favour among the big manufacturers, and is clearly on the way out, there remains a huge user-base of deployed devices that could take years to be replaced. Meanwhile, hybrid broadcast broadband television is yet to be adopted as a solid standard for interactivity.

Kroster on three different devices: Samsung Smart TV, HDMI connected to Cubieboard, Debian 7.1, Iceweasel 17, Fire hybrid broadcast broadband television (upper left); Sony XperiaU, Android 4.02 (upper right); and TELE System TS7900HD Set-to-box, DVI connected to Dell SP2008WFP multimedia home platform (bottom)

An ecological interactive application

As a contribution to the t-learning effort in Colombia, we have developed a novel game called Kroster. It features a bicycle tour through several Colombian landscapes, with different thermal floors and ecosystems. The goal of the game is to score as many points as possible during the ride. But in the process, the player will have the opportunity to spot and interact with each floor's endangered species. The underlying objective of the game is to get the public to learn about and appreciate the richness of their region's biodiversity, and to create empathy with the animals and plants through an understanding of their vital role in maintaining environmental equilibrium.

We took the opportunity of evaluating the above-mentioned options for interactive television by developing Kroster applications for a multimedia home platform and for hybrid broadcast broadband television. We also created the game as an Android application. The results are shown in this photo.

Unsurprisingly, the development of the multimedia home platform application proved to be complex until a Java television game library was crafted in house, easing the often confusing tasks of image positioning and resizing. Assets such as images and sound clips had to be downsized in order to comply with the memory limitations of the device. These limitations are not likely to go away, because newer and more powerful devices no longer support multimedia home platforms.

The development of a hybrid broadcast broadband television application was a mixed experience. Emulators and development tools are expensive, while open or free alternatives are scarce. Opera offers a virtual machine that is hard to customize, in our case to support the USB dongle we used for testing (PCTV nanoStick T2 290e). There is also a development plug-in for Mozilla Firefox (Fire hybrid broadcast broadband television) which provides basic

functionality, but falls short in the area of real interaction with broadcast signals.

The set-top boxes that we possessed, such as the Optibox Raptor HD and the Amiko Alien, were inadequate as neither of them supported both hybrid broadcast broadband television and DVB-T2 at the same time. There are of course other models that offer such a configuration, but the prices are still high and clearly beyond the buying power of most Colombian households.

We finally went for an in-house approach. A small set-top-box was crafted, using a system-on-chip, the Cubieboard, a customized Linux Debian 7.1 for ARM with recompiled kernel and modules, and the already mentioned DVB-T2 USB dongle. A Mozilla Firefox browser with a modified Fire hybrid broadcast broadband television extension was also installed on the device.

Using this relatively inexpensive arrangement, the testing and refinement of the hybrid broadcast broadband television version of Kroster was successfully completed.

The Android application was quickly adapted from the multimedia home platform original source code, thanks to the high portability between the different flavours of the Java programming language. Its performance is top-notch, as expected of a high-end smartphone.

There are currently no Android DVB-T2 enabled devices in the Colombian market, although there are early developments for other digital television standards, such as ESCORT's mobile television platform for the Advanced Television Systems Committee (ATSC). However, we were able to compile a custom Android kernel with support for DVB and our particular device, and with help from an OTG USB cable, Colombian digital television was seen on the screen of an Android tablet.

Conclusion

In conclusion, our advice would be to invest the necessary resources to develop applications that can be broadcast both through a multimedia home platform and through hybrid broadcast broadband television. In time, the multimedia home platform will probably be gone, and so it would be wise to cover hybrid broadcast broadband television from the start. But hybrid broadcast broadband television — while a promising technology — has yet to prove itself as a viable universal solution for interactivity. As for Android, the diverse nature of the devices and the need to go all the way down to the kernel to make a particular device work, puts the future of this platform in the hands of manufacturers. But again, with Android having such a big market share, it is best to have the Android application package file ready.

About the authors

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LTE 450 MHz technology for broadband services in rural and remote areas

Case study of Brazil

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In this article, we describe the Brazilian scenario using Long-Term Evolution (LTE) systems in the 450 MHz band as an economically viable model for leveraging the introduction of broadband services in rural and sparsely populated areas.

The Brazilian regulatory framework

Historically, Brazil has allocated spectrum below 1 GHz to point-to-point and point-to-multipoint voice services, audio and video broadcasting, and other specialized services, such as paging. A paradigm shift in spectrum regulation policies began in May 2010, when the National Broadband Plan *(Plano Nacional de Banda Larga)* promoted the 225–470 MHz band as an alternative to accommodate broadband services and applications. The main goal of Brazil's National Broadband Plan is to exploit the premium radio frequency propagation characteristics of lower frequency bands to increase cell coverage, a crucial aspect when it comes to providing services in rural and sparsely populated areas.

Later in that same year, the Brazilian Regulatory Agency *(Agência Nacional de Telecomunicações – ANATEL)* initiated efforts to set up rules for the deployment of broadband services in the ultra-high frequency band. In its Resolution 558/2010, ANATEL specifies the technical requirements for using the 450–470 MHz band in compliance with ITU recommendations for the Americas region. In line with the National Broadband Plan's goal of bringing broadband services to rural areas, ANATEL allocated two sub-bands of 7 MHz each in the frequency ranges 451–458 MHz and 461–468 MHz to fixed and mobile radio services operating in frequency division duplex mode. Effective radiated powers of base stations and terminals, and channel aggregation rules were also defined in Resolution 558/2010.

Following that move, in June 2012 ANATEL auctioned licences for the 450 MHz and 2.6 GHz bands for fourth-generation (4G) systems. As a direct consequence of the 4G auction, the 450 MHz band was split over four geographical areas, each one assigned to a main carrier already operating in the Brazilian market. The winning bidders have committed themselves to meeting requirements on service penetration and data rates in accordance with the schedule shown in the table.

By means of this initiative, the Brazilian Government expects to create conditions for increasing access to broadband services all over the Brazilian territory — in particular to the 30 million people living in rural and remote regions. Although ANATEL does not determine that such areas need to be covered using the 450 MHz band, it is likely that licence holders will adopt that band so as to benefit from its comparative advantages in terms of radio frequency propagation.

Long-Term Evolution

LTE is the standard under development by the Third Generation Partnership Project (3GPP) as an attempt to provide an evolutionary path towards next-generation cellular communication systems. The motivation behind the Brazilian initiative to leverage the deployment of LTE systems in the 450 MHz is twofold.

First, the National Broadband Plan requirements encourage the deployment of

4G licence requirements in Brazil

Deadline	Counties serviced (%)	Download rate (kbit/s)	Upload rate (kbit/s)
30/06/2014	30	256	128
31/12/2014	60	256	128
31/12/2015	100	256	128
31/12/2017	100	1024	256

Source: ANATEL, 2012.

An engineer examines Long-Term Evolution (LTE) equipment for a wireless system

Getty Images

systems and access technologies able to deliver high throughput and low latency in sparsely populated areas. Among the wireless access technologies currently available, LTE provides the highest spectral efficiency — its air interface conveys the largest number of bits over a given channel bandwidth. This is a key feature for any system operating in limited-spectrum and bandwidth-hungry environments. Another advantage of the LTE 450 MHz technology is its potential to support the roll-out of machine-to-machine communication services in rural environments, such as video surveillance, telemetry and tracking.

Second, serving the National Broadband Plan's target areas poses a challenge because, to be commercially feasible, the infrastructure investments and operational costs must be jointly optimized. In practice, this requires the deployment of large cells having coverage radii as large as 30 kilometres. An additional challenge in Brazil is the lack of backhaul infrastructure to transport traffic from cells to the core network in rural and remote areas.

3GPP standardization

In order to turn the 450–470 MHz frequency range into a standard band, 3GPP created a Work Item in September 2012. The purpose of that Work Item was to establish a global standard offering coverage of around 30 kilometres, and defining appropriate technical characteristics for the deployment of 4G systems in sparsely populated areas. As in the Brazilian countryside, such areas are typically characterized by the lack of backhaul and electrical power infrastructure. This challenging operational environment called for a new LTE profile designed for operation in the 450–470 MHz band, with radio frequency propagation conditions superior to those of existing profiles already standardized by 3GPP.

Within the scope of the Work Item, the Brazil's Telecommunications Research and Development Centre, CPqD, supported 3GPP in addressing topics such as channelization (band arrangement), coexistence with adjacent services, and performance of radio parameters for transmission and reception. These were some of the main challenges dealt with during this standardization process. All this work was conducted while taking into consideration relevant Brazilian regulatory aspects, such

as those defined in ANATEL Resolution 558/2010.

3GPP completed the standardization process of the 450 MHz band in September 2013. The corresponding specifications of this brand-new band, designated Band 31, will become available as part of LTE Release 12 specifications, and will maintain backward compatibility with all previous LTE Releases.

Technical challenges

Specifying and deploying LTE 450 MHz technology presents a number of challenges, most of which relate to interference management and system constraints to meet the need to provide extensive cell coverage.

The following specific challenges became apparent through the activities of CPqD during its participation in the 3GPP standardization process, and in its research and development efforts to develop LTE prototypes for the 450 MHz band.

Duplex gap: In Band 31, instead of narrower 1.4 or 3 MHz channels, the optimal channelization scheme that maximizes cell throughput (and, in turn, the number of users enjoying higher data rates) is achieved with 5 MHz channels. It is worth noting, however, that the deployment in the sub-bands allocated by ANATEL yields to a frequency spacing between uplink (at 452–457 MHz) and downlink (at 462–467 MHz) of only 5 MHz. This tight duplex gap creates an effect known as self-desense whereby spurious signals from the transmitter are caught up by the receiver thus degrading the system performance. This duplex gap is the smallest under analysis at 3GPP, making 450 MHz the most challenging band ever considered. Ways are available to tackle this problem, but at the expense of increased terminal complexity. User terminals constitute the most critical piece of equipment in a cellular network, as constraints on their cost, size and weight are more stringent than the constraints on base stations.

Interference management: The single 5 MHz channelization scheme implies the same channel being used in all sectors of the cell, and in all cells of the system. Sophisticated solutions are needed to mitigate the deteriorating effects of co-channel interference in the receivers. Another interference situation is caused by the transmission of narrowband high-power signals in channels adjacent to those in use by the LTE system. This scenario is well illustrated by television broadcasting, which with an effective radiated power of several kilowatts can dramatically affect the performance of LTE receivers operating nearby. The performance of the LTE system is also affected by impulsive noise generated by human activity, usually vehicles, machines and factories. The lower the operating frequency, the higher the noise level, meaning that systems operating in the 450 MHz band are more susceptible to noise than those operating in frequencies around 1 GHz or higher. This, however, is of less concern in rural areas where levels of noise produced by human activity are well below the levels observed in big cities. Although the technical means are in general available for improving system resistance to noise and interference, their adoption often increases the complexity and cost of the system.

Increased cell coverage: The deployment of cells with radii of the order of tens of kilometres places an additional burden on the development of LTE network equipment. Larger cells require higher transmission power, which directly translates into more complex power amplifiers. The longer reach offered by the 450 MHz band can compensate for part of this need, especially when high-gain antennas are used. As for the antenna, the designer should take into account aspects such as gain, radiation pattern, certification standards, ease of installation and, most importantly, physical dimension (recalling that the lower the operating frequency, the larger the radiating system).

Market aspects

In 2013, two companies announced the availability of LTE equipment (base stations and terminals for both indoor and outdoor use) capable of operating in the 450 MHz band. The two manufacturers have been conducting interoperability tests with Brazilian carriers, and the first LTE 450 MHz commercial networks should be up and running in compliance with the ANATEL 4G auction requirements by

2014. Furthermore, 3GPP standardization recognizes the use of LTE 450 MHz technology as an adequate solution for serving rural and sparsely populated areas, and endorses its application in markets other than Brazil as long as these have similar territorial dimensions and population density. Countries that already rely on the 450 MHz band to accommodate code division multiple access (CDMA) networks, such as the Russian Federation, Norway and Argentina, are potential markets for the LTE solution. The 450 MHz band is used by over 20 million people worldwide, who could also benefit from advanced services based on LTE technology.

LTE 450 MHz technology has the potential to become an important tool for providing access to broadband services in rural and remote areas. This, in turn, can contribute to economic and social development, and promote digital inclusion in developing countries.

About the authors

André Rocha *received his BE and MSc degrees in electrical engineering from the State University of Campinas, Brazil, in 1994 and the University of São Paulo in 2002, respectively. In 2010, he received an MBA degree from the* Fundação Instituto de Administração. *Since 2013, he has been with the* Centro de Pesquisa e Desenvolvimento em Telecomunicações, *where he is currently a marketing specialist with duties spanning from product marketing to innovation work for wireless networks.*

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Challenges to 5G standardization

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Interoperable, ubiquitous and dynamic are key objectives for fifth-generation (5G) communication systems and applications. These characteristics are also at the core of the main challenges that researchers, manufacturers, regulators and standardization bodies face when designing targeted strategies for the successful deployment of 5G enabling technologies.

Evolution of standards

Wireless communication standards have seen a rapid and multidirectional evolution since the start of the cellular era in the 1980s with the launch of the analogue cellular systems. Soon after, digital wireless communication systems emerged in a quest to satisfy mobility, quality of service and ever-growing data.

Despite the large variety of existing communication systems, each development has been motivated by the same goal: to provide universal service facilities to users, while maintaining or increasing profitability. While both aspects of this goal are strongly dependent on novel and smart technologies, the latter has also been a key factor in impeding rapid regulatory agreements that could speed up the adoption of interoperability on various infrastructural levels. This is a pity, because such agreements would make it possible to exploit dynamic access technologies to the full extent.

Backward compatibility, technology- and site-sharing, and convergence are key technological elements that — jointly with adequate regulatory agreements — will

enable ubiquity of communications on a highly personalized level. The vision of a 5G wireless communication system is one of universally deployable converging technologies that will enable wireless services and applications at a data rate of more than one terabit per second (Tbit/s), with coverage extending from a city, to a country, to the continents and to the world, that will enable user-centric mega-communications.

Myriad services

The challenges faced by standardization in relation to the next-generation wireless communication system (that is, 5G) are multifold. They are determined by the complexity of the emerging user and usage scenarios for which 5G must provide myriad high-quality services. Unlike single-purpose wireless systems, 5G will have the hard task of operating an ever-growing number of heterogeneous networked devices that can communicate with each other or with people or robots to satisfy dynamic and high-level user expectations.

The efficient wireless communication system that is needed will be able to follow the user regardless of location, and be able to adapt its traffic capabilities on demand in order to satisfy user and service requirements. Standardization work faces the tough challenge of responding to the high public demand for universal, dynamic, user-centric and data-rich wireless applications. The user-centric concept here also includes protection of privacy and maintenance of trust.

Technological requirements

Both standardization and technology developers are facing the challenge of diverse 5G technological requirements carrying equal weight in the provision of 5G services and applications.

Technological solutions for 5G should make it possible to eradicate or, at least, control the potentially dangerous aspects of ubiquitous communication, in particular those related to security, trust and the protection of personal data. Technological solutions should also offer reliability and dependability.

Researchers focused for years on finding the "killer application" for emerging wireless systems, but today the danger comes from the application business model itself. In order to boost profits, service

providers must enable access of personal data from one application to another, without allowing any visible control of what happens to the information afterwards. Beyond the technological challenges, this entails moral and ethical considerations, especially in relation to services and applications for critical infrastructure.

Thus, 5G standardization must define uncertainties relating, for example, to new threats to cybersecurity, trust or privacy; trends in economic growth around the world; public acceptance of wireless and applied-field technologies; and legislative restrictions. These uncertainties then have to be taken into account in regard to long-term trends in technological innovation, such as the increase in distributed computing, the new forms of ultra-fast wireless connectivity, miniaturization and automation, and an increasing focus on cost containment.

Communication, navigation, sensing and services

Convergence of technologies, ultra-high capacity, universal coverage and maximal energy and cost-efficiency are key characteristics of the 5G wireless system concept.

The enabling technologies converging into the 5G wireless system concept are communication, navigation, sensing and services. A determining factor for the first three is the availability of radio spectrum, through which information can be transmitted in relation to the service requested. Cognitive radio relies on sensing for better exploitation of the available spectrum, while high-frequency millimetre-wave bands used in terrestrial and satellite communications are able to satisfy the 5G capacity requirements and represent a solution to the limited availability of radio-frequency spectrum.

Small cell deployment within the coverage areas of cellular networks requires minimum pre-planning and can boost capacity, increase coverage and improve energy and cost-efficiency for the wireless provider, individual user and third parties that may be providing the communication interface. These benefits, however, may be partially lost because of increased interference and the inability of the network operator to manually configure the smaller cell to be properly detected and used by the mobile devices, or simply because of an inability to adapt to user needs. Proper self-optimizing procedures and protocols for fast network deployment and dynamic reconfiguration of small cells must solve the problem of how to deploy, where to deploy, and how to deal with the increased number of small cell sites. Such procedures and protocols thus carry the value of economically viable technological solutions.

5G services will rely on strong computational power to process the huge volume of data collected from various large-scale distributed sources. More specifically, 5G mobile devices will consume and produce data at the same time. Already today, most mobile devices are equipped with navigation capabilities (such as the Global Positioning System — GPS) and are able to report their location. The transfer of such an enormous load of information requires communication channels with the maximum possible capacity.

Novel antenna technologies and implementation of their hardware are crucial to maximizing throughput over the 5G communication channel. Beam forming with distributed elements is an interesting emerging technology, where the array elements are parts of different systems (that is, physically on different chips). This technology shows a potential for increasing the data throughput of distributed sources such as sensors or smart dust. On-chip integrated antennas can be used for distributed beam forming to maximize the data throughput of miniature sensor systems and other similar applications.

Using cloud computing capacities to provide and support ubiquitous 5G connectivity and real-time applications and services is a powerful way to automatically manage, analyse and control data procured from highly distributed and heterogeneous devices (sensors, actuators, smart devices). The cloud will be able to provide large-scale and long-lived storage and processing resources, as well as important backend resources, for the user-centric 5G ubiquitous applications delivered over the 5G wireless communication and network infrastructure.

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5G business case

The 5G wireless communication system should seamlessly bridge the virtual and physical worlds, offering the same level of all-senses, context-based, rich communication experience over fixed and wireless networks. Because 5G will be a plethora of interworking technologies governed by separate specifications, it is important to find technological solutions and standardize interconnectivity in order to enable end-to-end telecommunication service provision across technologies and operators.

The successful 5G business case must adopt an active integration strategy that merges the different realms of the enabling technologies with new business opportunities. Standardization then becomes an enabler for both a successful technological and business concept.

The first challenge for 5G standardization and regulation is to adopt technological concepts and regulatory decisions that remove the limit on data rates. Each user should have ubiquitous personalized 5G wireless access at very high sustainable data rates approaching the current Ethernet state-of-the-art of 10+ gigabit per second (Gbit/s). A ubiquitous and pervasive wireless network offering a sustainable 10 Gbit/s (reaching a rate of up to 1 Tbit/s in burst mode) can be used as an alternative to Ethernet and access to Tbit/s fibre networks. Thus, standardization should evolve 5G as a "Wireless Innovative System for Dynamically Operating Mega-Communications" (WISDOM).

Academic role

5G standardization faces the task of bundling multi-radio, multi-band air interfaces to support portability and nomadic mobility in a dynamic ultra-high data rate communication environment using novel concepts and cognitive technologies. Here, academic research and participation in standardization can play a crucial role. Standardization work should also recognize the specifics of the scenarios in various world regions (for example, developing countries) in order to stimulate profitable deployment and higher penetration worldwide.

Spectrum monitoring

Low-cost system for developing countries

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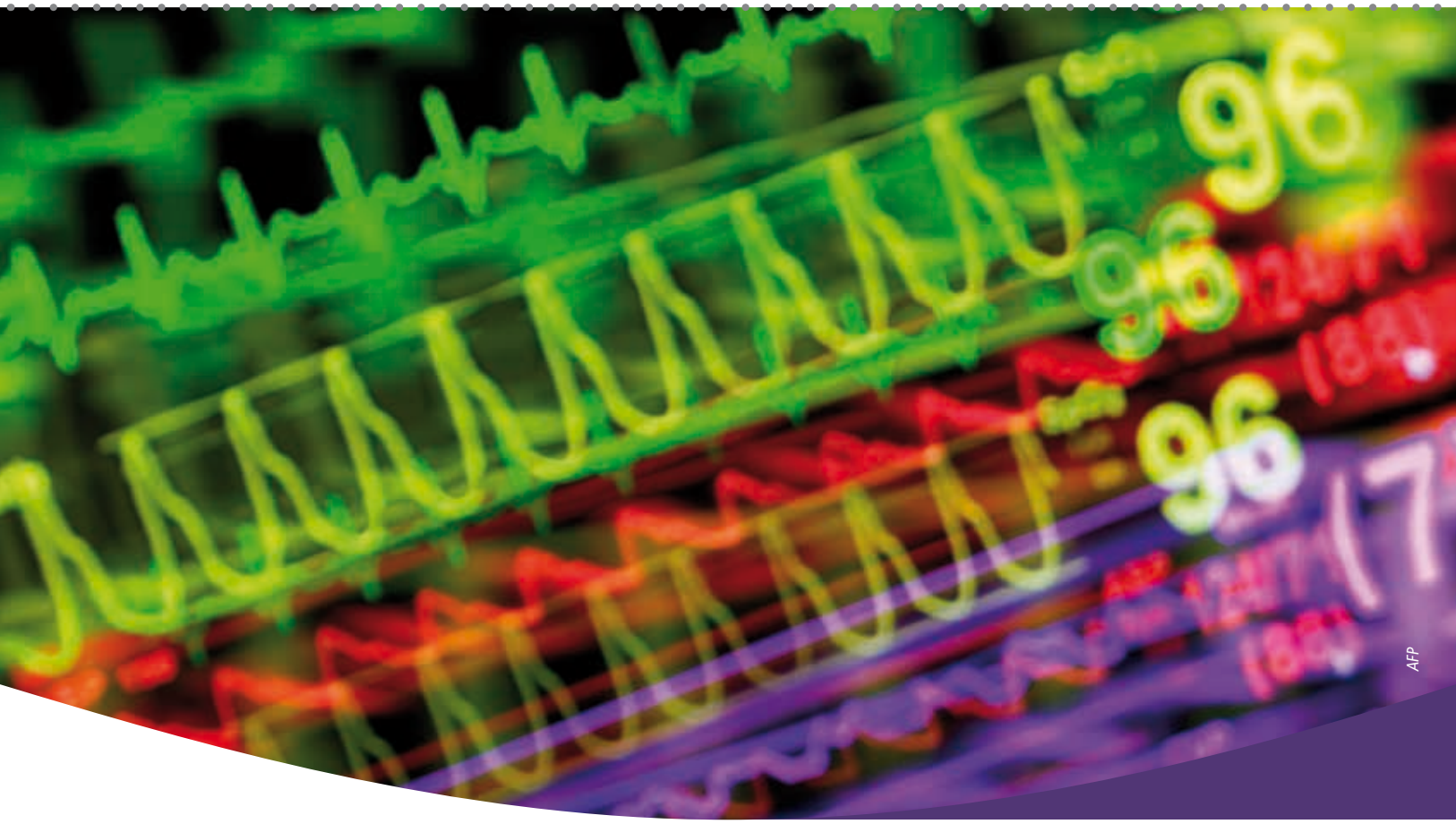
With the digitization of radiocommunications, and technological advances such as cognitive radio and cellular mobile systems, regulators need spectrum monitoring systems that have the flexibility to cope with the new environment.

ITU and regulators in Member States are aware of this challenge and have been working to update the ITU Recommendations and Handbooks. In 2011, a new version of the *Spectrum Monitoring Handbook* was published, and in 2013 ITU's Radiocommunication Sector (ITU–R) published a new Recommendation on spectrum monitoring evolution (Recommendation ITU–R SM.2039) as a result of work in Working Party 1C of ITU–R Study Group 1. In some developing countries, however, the cost of monitoring units and the demands of the new technologies can overwhelm regulatory bodies and budgets. Different technologies are currently being developed based on open hardware concepts, low-cost digital signal processing and open source software. These technologies can be used to support the evolving spectrum monitoring activities required by new concepts and architectures.

This article describes a spectrum monitoring system developed by our research group to support the monitoring activities of regulators in developing countries, to complement the high-level monitoring stations typically used by administrations. This system is part of Colombia's proposal for the evolutionary approach for spectrum monitoring systems under ITU–R Recommendation SM.2039.

Our specific objective was to design a simple, low-cost spectrum monitoring unit that could operate unattended. Our monitoring unit (which we call SIMON) is based on open source software and hardware,



and it supports monitoring and management tasks, as an adjunct to traditional fixed, transportable and mobile spectrum monitoring units with specific functionalities that are not standard in international systems. Our spectrum monitoring system (which we call SIMONES) was designed to fulfil the monitoring tasks specified in ITU–R Recommendation SM.1392 on "Essential requirements for a spectrum monitoring system for developing countries". The system is the result of cooperation between a company specialized in spectrum-related activities and our university, with the endorsement of the Colombian National Spectrum Agency.

Low-cost system

Our spectrum monitoring system, SIMONES, has four functional components: the monitoring unit (SIMON); a set of drivers to interact with commercial monitoring software (TES Monitor suite); an independent web interface; and a user-based drive test unit.

The system is based on GNU Radio and the Universal Software Radio Peripheral from Ettus Research. GNU Radio is an open-source toolkit that provides digital signal-processing blocks to implement software radios based on workflow structures, instead of using dedicated digital signal processing hardware. The Universal Software Radio Peripheral is the radio frequency hardware capable of performing signal processing using GNU Radio.

The monitoring unit consists of the radio frequency hardware, a wide range antenna, an Arduino-based control unit, and a set of batteries to offer additional autonomy. Because of the limitations in frequency range, bandwidth and sample rate of the Universal Software Radio Peripheral — and in general of all low-cost radio frequency hardware — the unit uses up to four peripherals connected to a radio frequency switch. The Arduino control unit manages the devices. It controls the antenna through the radio frequency switch and acts as a proxy between the peripheral and the client. It receives the control commands from the client and generates feedback information regarding battery status, Global Positioning System (GPS) location and the general health of the system.

The monitoring unit has two connectivity options: Ethernet and GSM. The first is used to perform measurements on site while the device is connected to monitoring software. It allows the user to see graphical plots, just like a standard spectrum analyser. The second is used to perform remote measurements based on alerts. Because of possible limitations in the communication channel while the device is working unattended, we decided that most of the measurement tasks would be performed inside the monitoring unit instead of sending out all the data captured by the antenna. The monitoring unit sends out alerts about specific spectrum licence violations, for example relating to bandwidth and power. The system has the capability to carry out non-ionizing radiation measurement procedures, according to ITU's Telecommunication Standardization Sector (ITU–T) Recommendation K.83. Our monitoring unit complements commercial units by sending information about frequencies and places that require more specialized measurement processes

Remote operation is possible because we are using the Universal Software Radio Peripheral E110, which is a fully autonomous device with radio frequency hardware and an embedded processor system capable of running GNU Radio. It can be controlled via XML-RPC calls, a standard communication protocol that is used in GNU Radio to send remote instructions to the unit. We have also tested the software with the Universal Software Radio Peripheral 2 and Nuand's bladeRF devices which need a permanent connection to an embedded computer that performs the digital signal processing operation. With those devices, it is possible to run the system in Ethernet mode or through a USB3 connection.

Integration with commercial software

We wanted to integrate our monitoring unit with the TES Monitor suite, a radio spectrum monitoring tool developed by TES America, a Colombian company that is sponsoring our spectrum monitoring system. The TES Monitor is capable of performing spectrum measurements, programming automatic measurement plans, and controlling multiple devices such as spectrum analysers, servomotors, and GPS. It is used by spectrum regulatory entities in Colombia, Costa Rica and Ecuador to control low tier monitoring stations across the country for spectrum management tasks. It is a C# application and is constantly evolving to include new functionalities according to regulatory requirements.

The integration of our monitoring system with the TES Monitor creates a basic spectrum monitoring station. In practical terms, the integration of our monitoring unit and the TES Monitor is achieved through a handler and a driver. The handler receives and process the power values measured by our monitoring unit and plots them on the interface. The driver controls the application's life cycle and sends XML-RPC calls to our monitoring unit to set parameters such as centre frequency and span. Both are written in C# and follow a general structure defined by the TES Monitor architecture.

SIMON and the web-based interface

Interaction between engineers and traditional monitoring tools has remained much the same since the 1960s. We wanted to design a modern web-based interface. Based on a review of existing tools, we propose a new interactive model based on frequency allocation tables, a new set of icons, and display changes that simplify and automate the main monitoring tasks.

We created an application that consists of two servers, one for control and the other for information flow. The first server allows the user to register new devices in the monitoring unit and to control them remotely. The user and the control unit are connected through the monitoring unit. The other server permits the flow of information coming from different devices to be sent to different clients. The web-based tool was created as the basis for a new version of TES Monitor.

The control server uses XML RPC calls to change the parameters of SIMON, and exposes a RESTFUL API to allow clients to perform those calls through the interface. It was developed using Django, a web framework for Python. The information server uses UDP to receive the data from SIMON and performs the delivery to clients using web sockets. This is done to increase performance and reduce latency. The control server was developed using "Node.js", a JavaScript framework for real-time applications.

Performance evaluation

We followed a test protocol to verify that our monitoring unit complies with the minimum technical requirements according to ITU Recommendations and the *Spectrum Monitoring Handbook*. We also validated our unit against Agilent EXA N9010A. We compared the web-based interface of our monitoring unit with that of the TES Monitor. While the web-based interface of our monitoring unit retains many of the characteristics of the TES Monitor interface, it also includes new concepts such as frequency allocation tables related to the country concerned.

For bandwidth measurement, we use the β/2 method as recommended in ITU–R Recommendation SM.443 and chapter 4 of the *Spectrum Monitoring Handbook* for systems based on fast Fourier transforms. For frequency measurements, we implemented the system to comply with ITU–R Recommendation SM.377, using the GPS locked reference oscillator for the Universal Software Radio Peripheral. Because our system is based on fast Fourier transforms

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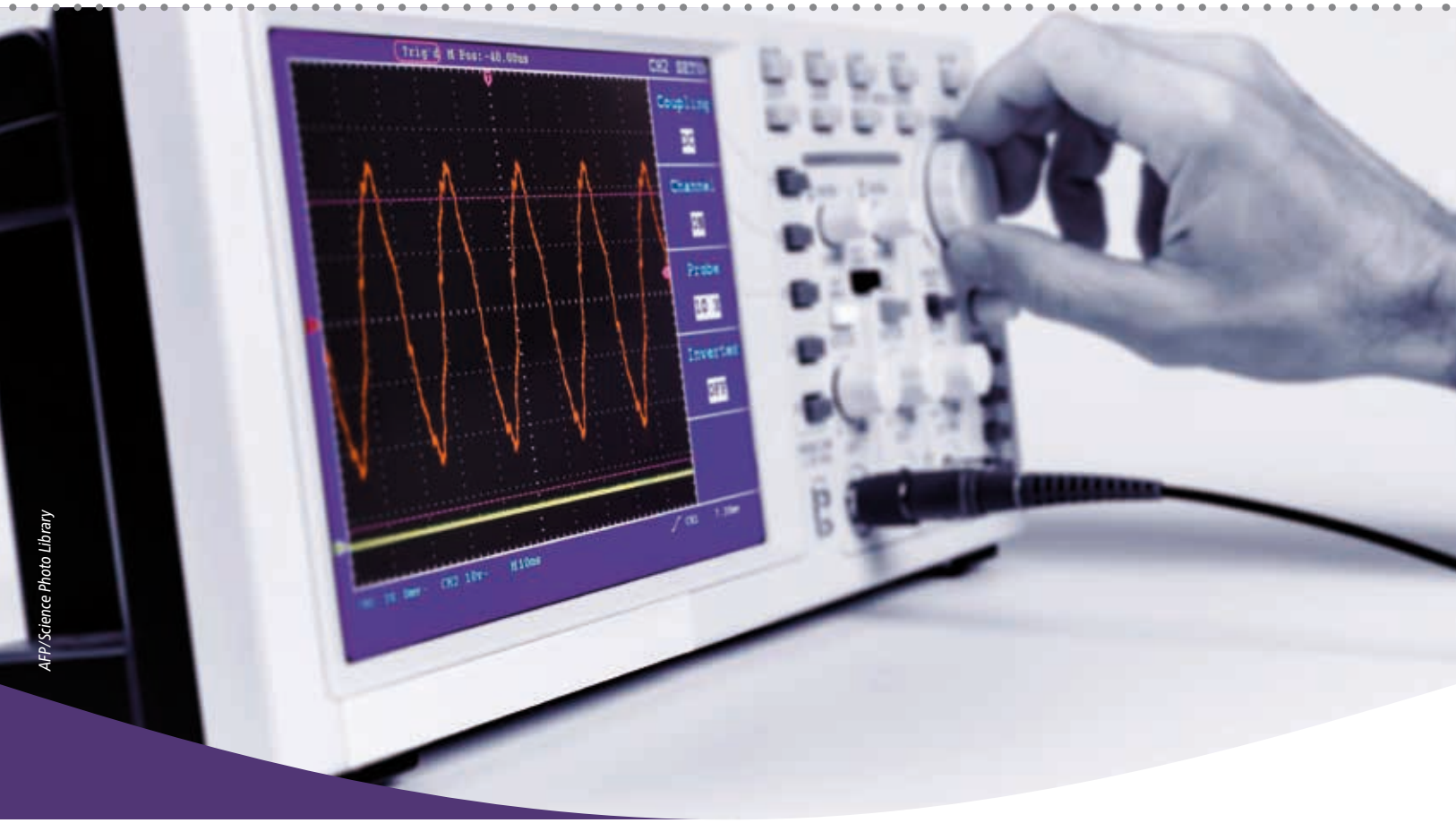

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and software-defined radio, we can also measure variations in bandwidth and frequency for digital modulations.

The system can automatically measure radio frequency level and power density, as specified in the *Spectrum Monitoring Handbook*. For power density, we implemented spectral power density using the discrete bins provided by the receiver by means of fast Fourier transforms. For radio direction finding, we use the method of rotating antenna, according to the *Spectrum Monitoring Handbook*. We have not yet implemented modulation analysis functionalities, but expect to do so in the near future.

The noise floor in our monitoring unit is higher than that in high-end spectrum analysers because of the electronic components in the Universal Software Radio Peripheral. This decreases the operational radius of spectrum measurements, as compared with high-end systems. Another limitation is the maximum bandwidth of 4 MHz per measurement, but this can be overcome using signal processing techniques. We can also use more than one peripheral to increase the bandwidth per measurement.

Future work

Over the next three years we are going to work on a project that includes a web-based version of TES Data and its integration with the ITU Spectrum Management System for Developing Countries (SMS4DC), the design of a non-ionization radiation measurement system, and a radio direction finding system using the Universal Software Radio Peripheral from Ettus Research and other open hardware devices. The direction finding system will implement methods based on antenna arrays and direction of arrival.

Chaos theory as the answer to limited spectrum?

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In the near future, there will be an uncountable number of sensors and terminal devices, while the number of users demanding wireless connection will increase exponentially. So far, frequency spectrum bandwidth has been limited because of the physical nature of spectrum. All the technologies that use spectrum are confronted by this physical boundary. How can we connect an unlimited number of devices using the limited spectrum bands? This is the ultimate question on spectrum usage. It has been a central theme of communications technology and will be one of the most crucial issues in the coming decades.

A paradigm shift from periodicity to chaos?

Today, spread spectrum communication is mainly third generation/Universal Mobile Telecommunication System (3G/UMTS). The ITU Radiocommunication Sector (ITU–R) standards for the evolution of communications technology notably indicate the recent development of high-end digital signal processing technology as well as diverse applications using different frequency spectrum bandwidths. Problems such as power control, energy efficiency and fading effects are currently more worrying than capacity.

The central research target of the Physical Statistics Laboratory at Kyoto University is to solve all these problems by taking a radical approach to information and communication technologies (ICT) using a relatively new area of mathematics and physics, namely chaos theory. This implies a paradigm shift from the periodicity regime that underpins the frequency spectrum to a chaos regime that will give rise to what we may call the chaos spectrum. The idea is to use the chaotic nature of telecommunication signals to develop a new unified communications technology beyond 3G code division multiple access

(CDMA) and 4G orthogonal frequency division multiplexing (OFDM).

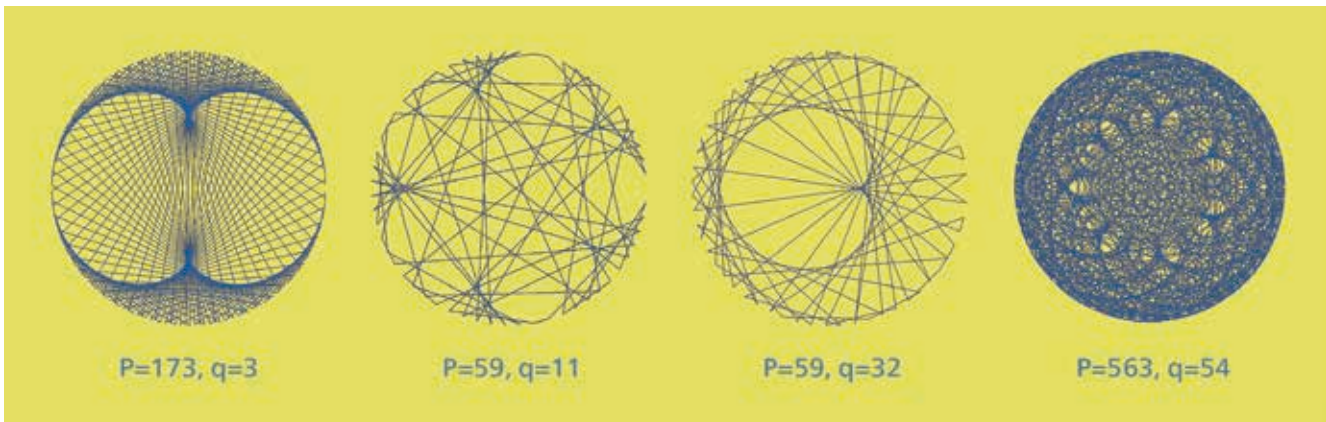
The very concept of spectrum comes from the frequency of periodic signals that can be arbitrarily used for communications. According to Fourier analysis (the hidden mathematics behind this mechanism), an arbitrary physical signal can be given by sum of sine waves which are orthogonal to each other. We thus sometimes refer to frequency spectrum as Fourier spectrum. Frequency spectrum is the basis of OFDM technology, which is widely used for 4G (IMT-Advanced) and wireless local area networks.

In contrast, chaos is an aperiodic phenomenon which has the property of unpredictable randomness. The existence of chaos in nature was discovered in the 1960s. A more recent discovery — of importance for ICT — is that chaotic signals can be used as the arbitrary signals that represent communications. An arbitrary physical signal can be given by the sum of a series of chaotic signals which are orthogonal to each other. In other words, the nature of the signal for the transmission of information can be equally well represented in the chaos spectrum as in the Fourier (frequency) spectrum.

The chaos spectrum has never been used for telecommunications but the crucial point here is that it is mathematically proven to be infinite. The figure below shows examples of chaos codes for communications.

Fundamental research on the role of chaos in ICT led to the presentation of the first and second laws of informatics to an international conference in 2012. These research results were published in 2013.

Examples of chaos codes for telecommunications, specified by prime numbers P and their associated primitive roots q



The first law of informatics states that secure information is always preserved. Chaotic signals can carry a measurable amount of information, and an identical amount of information can be retrieved from the chaotic signals. In other words, if certain information is converted into chaotic signals for the purposes of transmission, then exactly the same information is received when the chaotic signals are decoded. Chaotic signals in informatics are thus equivalent to a counterpart of reproducible thermal noise in thermodynamics.

The second law of informatics states that information sharing is irreversible. Alice and Bob can share secure information via chaotic modulation. According to the first law of informatics, zero information cannot be converted into the secure shared information that Alice and Bob have. So, what is the cost of sharing such secure information? If the cost is measured in terms of the generation of the chaotic signal, then the following inequality holds: the chaos generation costs for information sharing are greater than or equal to the cost of sharing secure information. Based on this fundamental inequality, it is clear that once Alice and Bob share secure information, they can never be in a situation in the future when they will not share that information. This is an irreversibility effect arising from the nature of information. As is well known, once published, information can never be secure.

Technological advantages of chaos spectrum

It is possible to suppress interference using a simple filter at the base station, implemented by chaos theory. This is an improvement over frequency spectrum techniques, which require an intervention by the end user.

Fading is caused by multichannel communications and is unavoidable. In fading channels, however, chaotic code signals are superior to conventional OFDM code signals because the receiver can use independent component analysis to separate the signals in chaotic mixtures.

Thanks to the invention of primitive root codes, we can construct an infinite

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number of orthogonal chaos codes which can be assigned to be an infinite number of addresses of things. If the Internet of Things means that several hundred billion things will be connected wirelessly, then that kind of super multiplexing technology with a potentially infinite number of orthogonal spreading codes will be needed.

In our view, chaos technology offers a promising future for 5G mobile communications.

About the authors

Ken Umeno *received his BSc degree in electronic communication from Waseda University, Japan, in 1990. He received his MSc and PhD degrees in physics from the University of Tokyo, Japan, in 1992 and 1995, respectively. From 1998 until he joined Kyoto University in 2012, he worked for Japan's Ministry of Posts and Telecommunications in its Communications Research Laboratory (currently National Institute of Information and Communications Technology). From 2004 to 2012, he was CEO and President of ChaosWare, Inc. He received the LSI IP Award in 2003 and the Telecom-System Award in 2008. He holds 46 registered Japanese patents, 23 registered United States patents and more than 5 international patents in the fields of telecommunications, security, and financial engineering. His research interests include ergodic theory, statistical computing, coding theory, chaos theory, information security, and social systems.*

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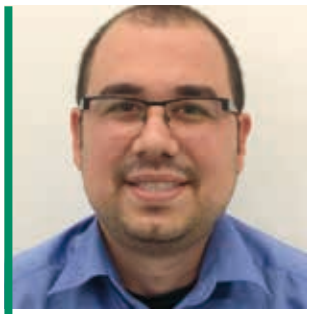
Innovations in optical networks

Telecommunications research and development in Brazil

Daniel M. Pataca

Juliano R. F. de Oliveira

Miquel Garrich



Neil G. Gonzalez

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Optical metro and core networks must support the continuously increasing demands of Internet traffic. The growth of Internet traffic is being fuelled by the emergence of new bandwidth-hungry services (such as video-on-demand and cloud computing) and new broadband access technologies, both wireless and based on fibre-to-the-x (FTTx). With this increase in traffic, optical networks face such challenges as technological heterogeneity and stringent requirements for optical spectrum efficiency.

Fortunately, optical transmission technology has evolved rapidly in the past decade in response to the increased demand for telecommunications services worldwide. Optical transport networks are now deploying 100 Gbit/s per channel wavelength division multiplexing (WDM) coherent transponders providing capacity per fibre of around 20 Tbit/s. However, in a few years time, this capacity will need to increase again to sustain network functionality.

One of the main challenges in this evolution is how to use network resources (bandwidth, power and so on) in an efficient way. The research community is therefore looking for innovations in advanced modulation formats, flexible-grid channel allocation policies, elastic and cognitive optical networks, software-defined networking, optical routers and amplifiers. This article summarizes some of the technological advances being achieved by the Optical System Division of Brazil's Telecommunications Research and Development Centre *(Centro de Pesquisa e Desenvolvimento em Telecomunicações — CPqD).*

High-capacity optical transmission

With the commercial deployment of 100 Gbit/s systems, interest is now focused on next generation optical fibre transmission technologies with bit-rates of up to 400 Gbit/s and 1 Tbit/s. Such systems may employ high order modulation formats, spectral shaping, and densely packed multicarrier transmitters (superchannels) in order to increase overall system capacity compared with the current technology. New paradigms have been proposed, such as multi-flow transponders, increasing flexibility and granularity. Recently, superchannels based on optical orthogonal frequency division multiplexing (OFDM) as well as Nyquist WDM have set records for transmission capacity, spectral efficiency and reach in deployed fibre networks. Such achievements demonstrate the potential for standardization and deployment of superchannels in the near future.

However, technological challenges must be addressed in order to enable transponders' data-rate reconfiguration for flexible transmission systems, broadband optical amplification schemes to alleviate optical signal-to-noise ratio requirements and flexible-grid wavelength selective switches to allow variable bandwidth allocation. Moreover, reach-adaptable line rates based on bandwidth adjustment are expected to cover both metro and long-haul applications in a single optical fibre system infrastructure. In particular, orthogonal frequency division multiplexing has been proposed as a potential solution to support flexible granularity service aggregation by adapting the modulation format and the number of optical subcarriers according to channel conditions (for example, considering optical signal-to-noise ratio). However, orthogonal frequency division multiplexing requires orthogonality between optical subcarriers and a wide dynamic range at the transmitter and receiver. New challenges in transmission include the development of technology for multicarrier reception, joint digital signal processors for superchannel detection, and non-linear compensation.

Using an optical networking testbed at the *Centro de Pesquisa e Desenvolvimento em Telecomunicações,* the Optical System Division has recently investigated and experimentally validated a polarization-domain hybrid quadrature phase shift keying 16-quadrature amplitude modulation Nyquist terabit superchannel, envisioning a fully time frequency polarization adaptive optical system for next generation elastic optical networks. In addition, the Optical System Division has investigated a reconfigurable optical transmitter based on optical pre-filtering and quasi-Nyquist generation, which provides high modulation formats with low spectral occupancy

and allows applications on different transmission network scenarios. On the receiver side, coherent detection is used to recover the transmitted signal, followed by a real-time scope that samples, digitizes and stores the received signal. The stored data are processed offline using a set of algorithms to recover transmitted information and the bit-error-rate values of each test are computed.

Optical networking and subsystems

A suitable network infrastructure is needed to cope with high-capacity transmission. In this context, the Optical System Division is continuously developing state-of-the-art network elements, including wavelength selective switches, multi-cast switches and reconfigurable optical add/drop multiplexers. Such developments reduce the need for manual intervention by technicians (for example, to fix faults or when upgrades are needed). High optical signal-to-noise ratio requirements must be met to cope with the evolution of transponder modulation formats, thus optical amplifiers must be continuously enhanced to improve optical performance in reconfigurable/dynamic optical networks. To address this challenge, the Optical System Division is currently investigating several hybrid optical amplifiers.

The use of new modulation formats decreases the accuracy of out-of-band optical signal-to-noise ratio measurement, because the noise floor becomes more difficult to detect. The Optical System Division has therefore developed a mechanism that measures the optical signal-to-noise ratio with an in-band monitor that is insensitive to first order dispersive effects.

The Optical System Division is also aligned with the growing trend to use standardized solutions for northbound network interfaces and equipment modelling languages. By employing graph-based algorithms at the component level, complete abstractions can be created for network operators in order to ease network management. The complexity of subsystems can be omitted, and future optical networking approaches (for example, software-defined networking or network functions virtualization) can easily be integrated. The graph-based approach provides a basis for alarm correlation and advanced path computation. It also provides the information needed for multi-agent oriented problem

solving, which is not feasible for current installed hardware.

Future research needs

Despite the reduced need for manual intervention and the high capacity achieved nowadays in optical networking, there are still some areas where progress is needed. The design of reconfigurable optical add/drop multiplexers can still be improved or optimized in terms of space, power consumption and cost. Also, rerouting times need to be reduced to the order of hundreds of milliseconds in order to cope with node or link failures. To increase the capacity of current optical systems, optical amplifiers need to evolve in the near future from single core to multi-pumped multi-core erbium doped fibre amplifiers.

Separation of the control and data planes allows network virtualization, but it is still impossible to guarantee isolation in optical networks with today's technology. In traditional networks, transponders and reconfigurable optical add/drop multiplexers are fixed in terms of spectrum grid, modulation format and bit rate. In contrast, in elastic networks, transponders and reconfigurable optical add/drop multiplexers are flexible, and some erratic control algorithms can cause interference across wavelengths belonging to different virtual optical networks. This is a critical area of future research in optical networks.

In the transmission area, new paradigms have been proposed, such as multi-flow transponders which increase flexibility and granularity. New challenges include the development of technology for multicarrier reception, joint digital signal processors for superchannel detection, and non-linear compensation.

Photonics integration is a key area for the development of integrated silicon photonics circuits to be used in multi-carrier optical transmitters and multiple coherent optical receivers integrated with narrow bandwidth tunable lasers. Future improvements to flexible-grid wavelength selective switches are expected to reduce switching response times and optical losses in order to ease network operation.

Software-defined networking and optical network virtualization will also need to evolve in many respects, including interface standardization, multiple-layer integration, as well as resources isolation.

Brazil's Telecommunications Research and Development Centre

The Centro de Pesquisa e Desenvolvimento em Telecomunicações (CPqD) is an independent institution whose main objectives are to increase Brazil's competitiveness and to further the digital inclusion of the country's society, based on innovative information and communication technologies (ICT). Its extensive research and development programme, the largest of its kind in Latin America, has produced ICT solutions for both private and public corporations in the communications, multimedia, financial, utilities, industrial, defense and security sectors. Its Optical System Division is in charge of numerous projects devoted to the research and development of new optical systems (transmission and reception), subsystems (amplifiers, optical routers and network monitoring) and networks (software-defined networking and smart algorithms) for future high-capacity elastic optical networks.

Impact of environmental temperature fluctuations on G.fast performance

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The transmission parameters of metallic cables are influenced by the temperature of the surrounding environment. Given that the newly developed G.fast system will occupy a wide frequency band, its transmission performance could be measurably affected by temperature fluctuations in real applications. Temperature oscillations are noticeable especially in mild climate regions, where the air and soil temperatures at shallow depths may vary significantly, mainly between winter and summer. The results of simulating G.fast performance in a temperature fluctuating environment, described in this article, could be helpful in identifying the potential challenges to G.fast deployment in practice.

Fast last-mile access

Today, the deployment of optical fibre in last-mile network segments in Europe is still slow, largely because of the need for massive capital investment. To support the expansion of fibre-to-the-x (FTTx) lines as well as more intensive exploitation of existing metallic cables in access networks, the ITU Telecommunication Standardization Sector (ITU–T) has recently initiated the development of a new generation of xDSL systems called G.fast. The aim is to reach transmission rates of 1 Gbit/s for very short metallic loops (not exceeding 300 metres). G.fast will embody an innovative approach partially based on existing xDSL principles, and its frequency band will be extended up to 106 or 212 MHz.

Most fixed-access networks in Europe still consist of multi-quad and multi-pair metallic cables. In cities and urban areas, these cables are usually installed at shallow depths underground. Aerial installation is typical for rural areas and is common in southern European countries. In cities, cables to premises are generally installed below roads and footpaths at depths of around 0.5 metres. Most of Europe is located in a mild climate zone, where air temperature oscillations between summer

and winter or day and night during summer are significant. The soil temperature fluctuation is not as intensive, however, there are still significant soil temperature differences especially between the summer and winter seasons. Because of this, the transmission parameters of metallic lines, especially their attenuation and electrical conductivity, also fluctuate.

These fluctuations are important mainly at high frequencies and for wideband transmission systems, and so are likely to affect the performance of the newly developed G.fast subscriber lines. The simulations presented in this article are based on typical temperature conditions for underground metallic cables in central Europe, as well as on the most recent models available of metallic lines and the G.fast system.

G.fast performance estimates

In central European countries, typical air temperature differences between the coldest and hottest days during the year are between 25°C and 30°C. Soil temperature fluctuations are however not as intensive as air temperature oscillations. The soil temperature at a depth of around 0.5 metres can easily fluctuate between 0°C (January) and 23°C (July), although fluctuations may be greater if the seasons are extremely cold or hot.

The electrical resistance as well as the attenuation of a metallic conductor depends on its temperature. All the simulations described here were performed for a typical buried 26 American wire gauge (AWG) distribution cable filled with a gel and containing 75 star-quads. This type of cable is often used for installations in underground premises. The simulations were performed for a typical temperature scenario in central Europe, with maximum and minimum soil temperatures between 0°C and 25°C at a depth of 0.5 metres.

The simulations were performed for both G.fast frequency versions — 106 and 212 MHz. These bands are notched on low frequencies (up to 2 MHz), on frequencies used for FM (or DBA) radio broadcasting and also on frequencies occupied by emergency systems and amateur radio channels.

The first simulation was performed for 106 MHz G.fast in a temperature range from 0°C to 25°C, with the length of a cable between 50 metres and 350 metres. The resulting data rates are presented in Figure 1.

As shown in Figure 1, the performance of G.fast is influenced by the environmental temperature, as expected. But the divergences between estimated G.fast data rates calculated for various temperatures differ, depending on the length of the cable, as illustrated in Figure 2.

The G.fast lines approximately 270 metres long are the most temperature sensitive using the 26 AWG metallic cable, with a temperature increment of 5°C expected to cause a decrease of approximately 6 Mbit/s in the transmission rate in this case. Thus a difference of almost 31 Mbit/s is to be expected with a temperature difference between 0°C and 25°C for a 106 MHz G.fast line with the length of 270 metres.

Figure 1 — Estimated data rates of 106 MHz G.fast for 26 American wire gauge underground cable in a temperature range between 0°C and 25°C

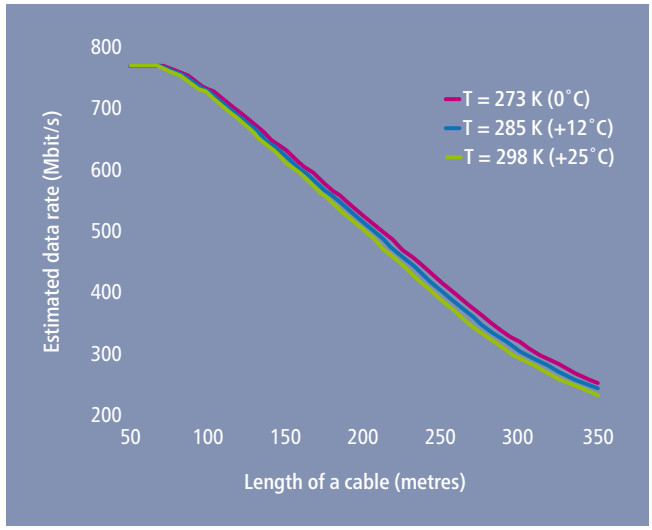
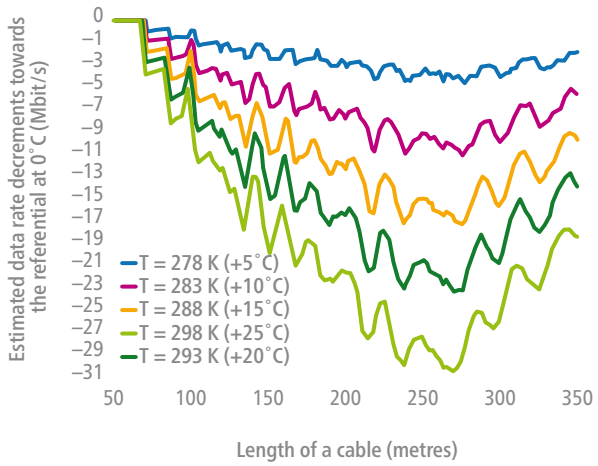


Figure 2 — Data rate decrements of 106 MHz G.fast towards the reference temperature of 0°C



The same simulations were performed for 212 MHz G.fast, with identical temperature conditions and cable parameters. The estimated data rates for 212 MHz G.fast are presented in Figure 3

The estimated data rates for 212 MHz G.fast show similar behaviour to that of 106 MHz G.fast, although the decrease in data rate shown in Figure 3 varies markedly with fluctuating temperature. A more detailed comparison with the decrements calculated towards the reference data rate at 0°C is illustrated in Figure 4.

For 212 MHz G.fast, the most temperature sensitive subscriber lines are approximately 150 metres long, with every 5°C increment decreasing the transmission rate by approximately 13 Mbit/s. The maximum difference between summer and winter transmission rates (according to the simulations) is almost 67 Mbit/s for 150 metres long 212 MHz G.fast on 26 AWG underground cable.

Figure 3 — Estimated data rates for 212 MHz G.fast for 26 American wire gauge underground cable in a temperature range between 0°C and 25°C

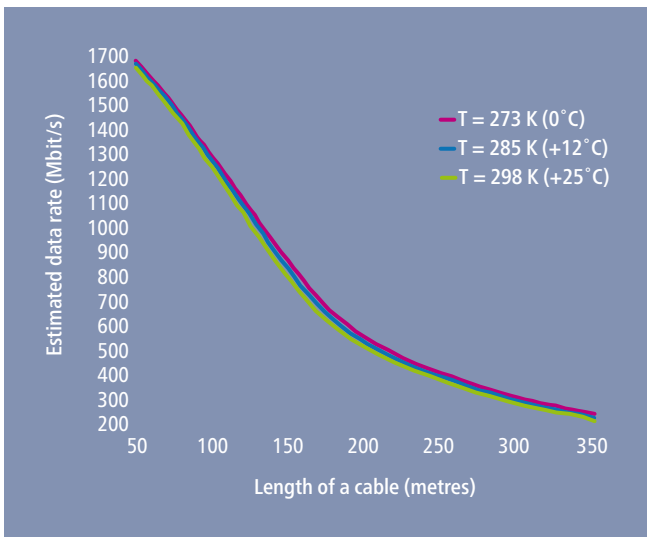
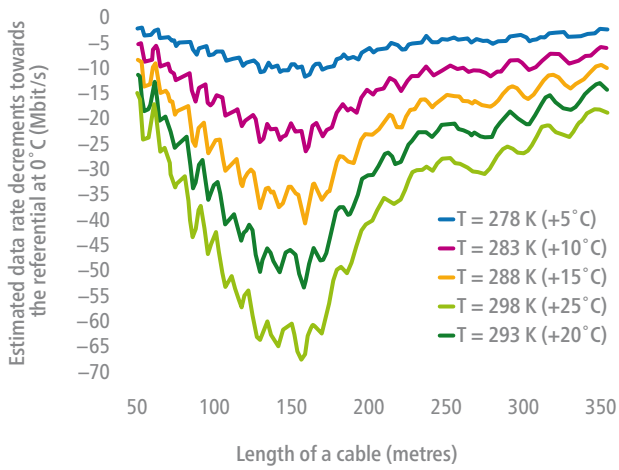


Figure 4 — Data rate decrements of 212 MHz G.fast towards the reference temperature of 0°C



Workers at China Mobile carry new optical cables to replace broken ones in Zhangmu Township, Nyalam county, following a heavy snowstorm

AFP

Cable length counts

All the simulations demonstrated that the temperature fluctuations in real applications may cause measurable differences in G.fast transmission rates. This is especially the case in G.fast lines with critical lengths, where data rates may vary by tens of Mbit/s as a result of environmental temperature fluctuations between the summer and winter seasons. These critical lengths of metallic cables (the most temperature sensitive G.fast line lengths) evidently depend on the selected frequency profile and on the type and parameters of the metallic cable used.

The conclusion is that, in practical applications of G.fast, measurable differences in data rates should be expected in zones where there are significant temperature variations.

About the author

***Pavel Lafata** received his MSc degree in engineering in 2007 and PhD in 2011 from the Department of Telecommunication Engineering, Czech Technical University in Prague. He is currently working towards an associate professorship. His research activities are focused mainly on fixed high-speed access networks, modelling and simulation of both metallic and optical lines, xDSL and G.fast lines and passive optical networks, and problems related to their optimum topologies.*

Ageing society and ICT

A new growth industry?

Naoko Iwasaki

Associate Professor at the Institute of e-Government, Waseda University, Tokyo, Japan

Societies are ageing throughout the world, and information and communication technologies (ICT) offer responses to this dynamic social change. A good ICT policy will provide the services and tools that match the needs of elderly people. It is especially important to improve their accessibility of e-services as a way of enhancing their daily lives. There are four areas in which ICT can play an essential role for elderly people: infrastructure; lifelines; communications; and enhancement of the richness of daily life. In Japan, for example, older people particularly appreciate applications that offer them access to social welfare services and regional activities. They also benefit from access to educational opportunities, for example through Internet classrooms.

Japan as a forerunner of ageing societies

Japan has the highest ratio in the world of 65-year-olds to total population — at 25.1 per cent in 2013. It also has the longest life expectancy. In 2012, the average lifespan was 79 years for men and 86 years for women. The ageing society will pose a challenge not only to Japan but to all countries of the world.

Although at present the percentage of elderly people in developing countries is relatively low, according to United Nations estimates their proportion is increasing more rapidly in those countries than in developed ones. Thus, developing countries will have less time to adjust to the consequences of population ageing. Since the 1980s, there have been more older people in developing countries than in developed ones. In China alone, the number of people over 60 years of age is expected to reach 400 million (26 per cent of the total population) by 2040, which is more than the combined current populations of France, Germany, Italy, Japan and the United Kingdom. There is no time to lose in putting policies in place to respond to the needs of elderly citizens.

European and Asian countries, such as China and the Republic of Korea, are watching how Japan is preparing for its silver society. Japan has an opportunity to construct a model for the efficient use of ICT in an ageing society.

Social consequences of Japan's ageing population

About 40 per cent of the total population of Japan in 2050 will be aged 65 years or more. Not only that, but the total population of Japan has been decreasing gradually since 2004. Japan is the only society in the world today that is experiencing both population decrease and super ageing. This social change will make current policies obsolete and will require new approaches.

The statistics presented in the table indicate some of the social trends associated with the ageing population in Japan, but they do not paint the full picture. Based on the statistics available in 2013, it is expected that 40 years from now, the total population of Japan will have decreased by more than a quarter.

"According to a survey of about 300 people aged over 60 years carried out by the Institute of e-Government, Waseda University, and other research centres, some 80 per cent of elderly citizens in Japan can be categorized as "active ageing". About 80 per cent of retired people are looking for jobs but only 20 per cent of them can get jobs.

The ageing society in Japan: 1960, 2010 and 2030

	1960	2010	2030 (projection)
Number of people aged over 65 years	5 million	29 million	37 million ↑
Proportion of people aged over 65 years	5.7%	23.0%	31.6% ↑
Life expectancy at birth (years)	Men 65.3	Men 79.6	Men 82.0 ↑
	Women 70.2	Women 86.4	Women 88.7 ↑
Total fertility rate	2.00	1.39	1.34 ↓
Mean number of household members	4.52	2.46	2.27 ↓
Households with heads over 65 years	–	15 680 thousand	19 031 thousand
of which one-person households		29.7%	37.7%↑
Social security expenditure	0.7 trillion yen	108.1 trillion yen (2011)	151.0 trillion yen (projection for 2025)
Place of death	Hospital 18%	Hospital 78%	–
	At home 71%	At home 13%	

Accessibility and usability

According to a survey of some 300 people aged over 55 years carried out in 2010 by the Institute of e-Government, 80 per cent of respondents were able to use ICT and did so every day. Of these, 50 per cent learned how to use the devices on their own, while 20 per cent were taught by others; and 18 per cent considered that no learning or teaching was needed because the devices could be intuitively understood and 6 per cent found that the instructions for use of the devices were easy to follow. Most elderly people in Japan can use a mobile phone and the mobile Internet. Those who cannot use these ICT tools want to be able use them if they have the opportunity to learn how.

Silver ICT business

Older people hold 60 per cent of all individual financial assets in Japan, worth 1.6 quadrillion yen. Half of national healthcare expenditure is spent on people aged over 65 years. About 70 per cent of people injured during major disasters, such as the 2011 tsunami, are elderly.

The potential range of the ICT market serving elderly consumers — which we call the silver ICT business — is extremely wide

Japanese actress Shinobu Otake displays the "Raku-Raku smartphone" designed for the elderly

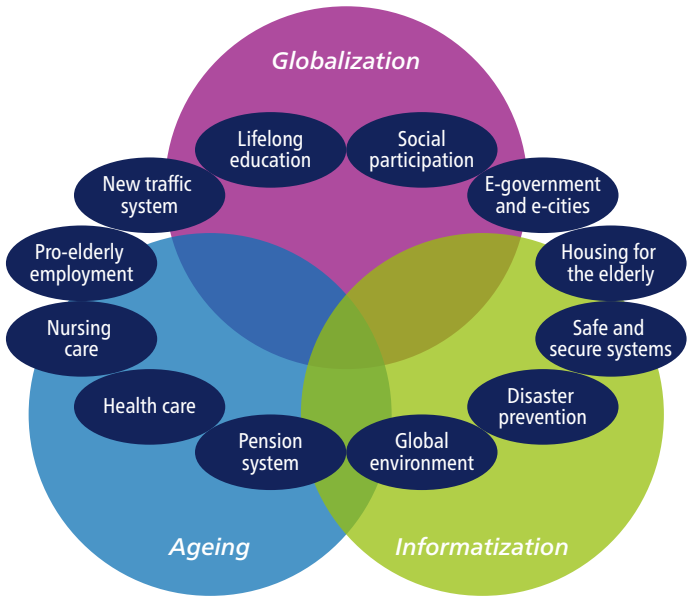
AFP

in Japan, including e-participation, e-government and e-health (see chart). These industries will expand more and more with the super-ageing of society in the future. ICT devices and tools that older people find convenient to use will help to bridge the digital divide that currently exists between active and inactive elderly citizens, and may become their lifeline in the event of a disaster.

How much of a market could the silver business create? According to a Waseda University estimate, the size of a silver ICT business could reach a value of 1 USD trillion by 2035.

One of the challenges faced in an ageing society is the lesser physical capability of older people. This is a challenge that ICT may be able to overcome. For example, in 2001 NTT DOCOMO pioneered

ICT services and applications that can be adapted for the ageing society



the introduction of a mobile phone, the Raku-Raku phone, that elderly people find easy to use. Social media such as Twitter, Facebook and LINE are now part of our daily lives, and played an important role in disseminating information during the disaster that hit Japan in March 2011.

Research needs and collaborative efforts

The ageing of society will shape Japan's future. Given the challenges, it is important to explore and promote ICT-enabled innovations to meet the special needs of older people.

The first step is to review current public initiatives such as e-health and e-accessibility, and to assess the extent to which infrastructure, devices, interfaces, services and applications meet the requirements of elderly people in Japan.

In order to find solutions to the challenges posed by an ageing society, the Institute of e-Government, Waseda University, is cooperating with ITU, as well as Asia-Pacific Cooperation (APEC), the Organisation for Economic Co-operation and Development (OECD) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), among other international organizations.

An APEC-funded project has created an effective platform for knowledge exchange on innovation for assistive ICT applications for the ageing and for people with disabilities. The project has evaluated experiences in implementing these technologies and providing associated training in participating economies. It has also created a new business model for silver ICT innovation.

As a part of an OECD initiative in 2011, Japan along with Denmark, Finland, Italy, the Republic of Korea and Sweden explored effective measures to foster the development of a silver ICT economy. They concluded that the most important step is to create an effective platform for knowledge exchange on how constantly evolving ICT can be applied to meet the needs of a rapidly ageing population.

Since 2005, UNESCO's UNITWIN Network has worked to provide assistance in looking for solutions to the various challenges of e-disaster education and to offer recommendations on improving the implementation of e-public safety.

ITU could lead the world community in this field. The standardization of ICT devices will improve usability and accessibility, supported by an ICT literacy programme for the elderly. Specific suggestions arising from research undertaken at Waseda University include building an institutional framework for convergence between the information society and ageing society, using Japan as a testbed for ICT innovations to assist elderly people, and strengthening international collaboration between ITU, OECD, APEC and UNESCO to form a silver ICT network.

About the author

***Naoko Iwasaki** received her master's degree and PhD from Waseda University, Tokyo. Her research interests focus on the convergence between the information society and the ageing society, as well as on the role of chief information officer in the private and public sectors. Her publications include "Aging society and ICT" and "Silver ICT innovation saves super aging society".*

Small cell cloud

Load balancing of computational resources allocated to users in a small cell cloud

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By integrating computing capabilities to small cells, computation can be offloaded from user equipment to a so-called small cell cloud (see Figure 1). In this case, the proximity of users and small cells offers the advantage of shortening latency for mobile cloud computing applications. If a user decides to offload an application to the small cell cloud, then the computation resources must be allocated at specific cells that have sufficient computational power to deliver results in time.

In this article, we propose an algorithm for balancing the computational load among cells, taking into account the delay requirements imposed by users and the available computational resources of the cells. Analysis of performance of this novel method of load balancing confirms the efficiency of the algorithm, leading to increased satisfaction among users with the quality of service provided through the small cell cloud.

User preferences

On one hand, users require huge computational power but, on the other, they also want mobile equipment that is light in weight and with acceptable size. Cloud computing can be exploited to overcome the limited computational resources of user equipment. However, while a conventional centralized cloud offers high computational and storage capacity, it also introduces high latency in data delivery. Also, the cost of data delivery through the network is not negligible, and a high volume of data can congest the network. Moreover, concerns about the security and privacy of users' personal data at a remote place may be a limiting factor as regards the usability of the centralized cloud.

To overcome these weaknesses, the cloud should be deployed as close to the user as possible. In the architecture of fourth-generation (4G) mobile networks, the nearest place where a computing or storage unit can be deployed is a serving base station. Considering base stations as part of a distributed cloud introduces new opportunities for improving latency, reducing the cost of data delivery, and — in some cases — overcoming privacy and security problems. Furthermore, energy consumption of the user equipment can be lowered if only small cell base stations are considered, because these are closer to the user than macro cells. Enhancement of small cells by integrating computing capabilities within them is part of a small cell cloud concept introduced by the European FP7 project TROPIC ("Distributed computing, storage and radio resource allocation over cooperative femtocells" (http://www.ict-tropic.eu). Such an approach enables user equipment to offload parts of tasks or complete tasks to nearby small cells.

In the small cell cloud, the cells in the user's vicinity are grouped into clusters, providing computing capabilities to the user equipment. If the user equipment indicates a need to offload a computation, the most suitable set of nearby cells is selected to perform the task. The cells should be chosen in such a way that users' requirements in terms of quality of service (which we represent in our analysis by overall latency) are fulfilled.

Algorithm for balancing loads

To maximize efficiency in allocating computational resources, we need to balance the load among the cells. Proper load distribution enables better use of the overall capacity of the system and it also allows the processing of more requests while still guaranteeing quality of service.

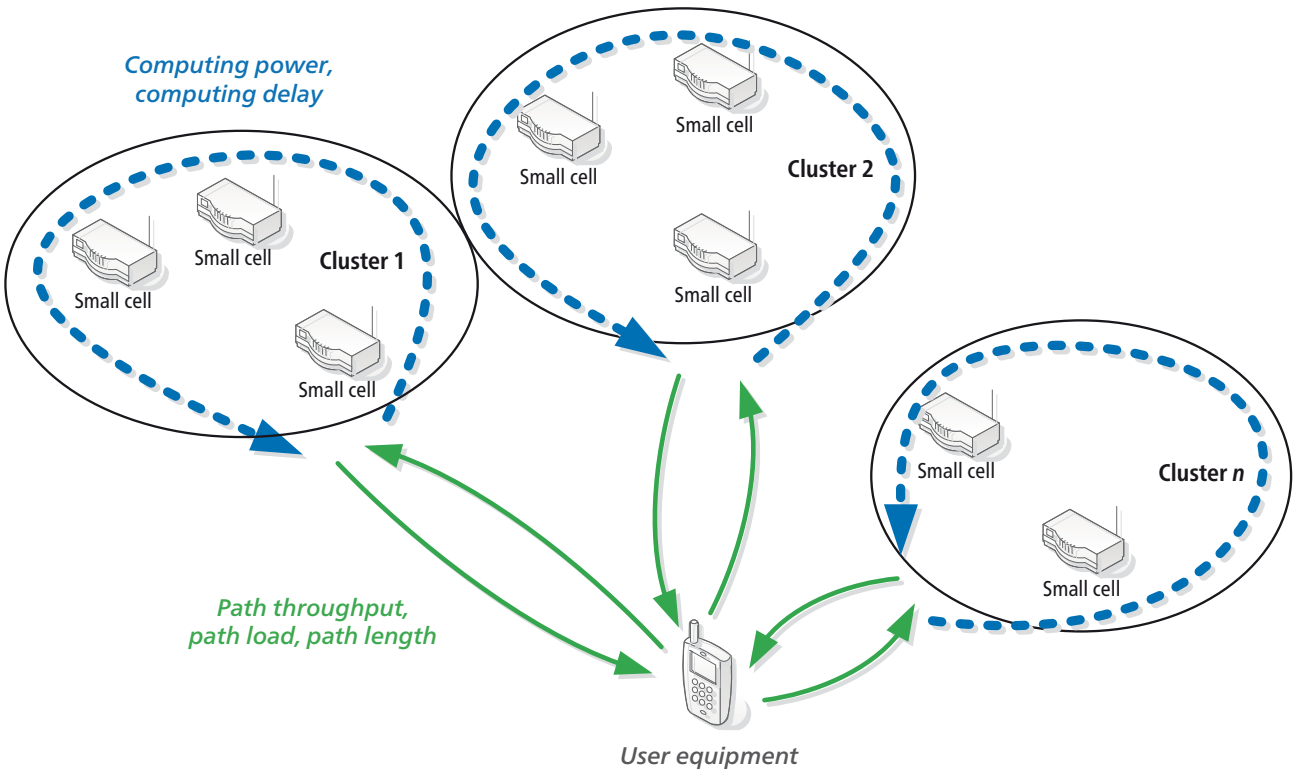
Load balancing algorithms can be static or dynamic. In static load balancing algorithms, the cluster is defined before the calculation is started and remains unchanged during the calculation except when an unexpected situation — such as node failure — occurs. Dynamic load balancing algorithms allow changes in the cluster during the computation, and these algorithms are generally more effective. Nevertheless, the static approach is more suitable for the small cell cloud because of the significant cost and duration of migrating virtual machines from one cell to another. In addition, static load balancing is easier to implement and generates less overhead. We therefore focus solely on static load balancing here.

The new load balancing algorithm that we propose differs from existing algorithms in that it considers not only the load of cells, but also the quality of service requirements of users. The algorithm selects the cluster that is able to deliver results for a user not as soon as possible but just before the maximum latency required by the user expires. In other words, our new algorithm is based on knowledge of the maximum handling time that users will tolerate.

Each cluster of the system is characterized by features of the path from the user equipment to the cluster and back (composed of the radio and backhaul parts) and by the computing capacity. The path is described by throughput, length and load. The computing performance of the cluster is defined by its computational power and computational load. All those characteristics of the cluster and path can be expressed by one parameter — handling latency. For an incoming request, the handling latency is composed of the delivery delay and the computation delay.

The objective of the proposed algorithm is to select a cluster of computing cells so that the overall computing performance of the whole system is maximized, and the required quality of service is ensured for the largest number of users.

Figure 1 — Parameters for cluster selection with load balancing



Results of performance evaluation

We compare our new algorithm — which we call the "Minimum difference" algorithm — against the "Randomized", "Round Robin" and "Central Manager" algorithms. The basic static load balancing approach, known as the Randomized algorithm, selects the cells for computation randomly. The Round Robin algorithm maps requests to individual clusters in a predefined order. The Central Manager (Minimal) algorithm selects the cluster with the lowest load, for every request. We also consider a Central Manager (Maximal) algorithm, which selects the most heavily loaded cluster for each request.

For each test run, we assume that there are 100 clusters and that 100 requests for computation arrive at each cluster. To simulate a highly loaded system, we assume that all the computations arising from the generated requests are long lasting (that is, they all last longer than the period during which the system is observed). Hence, the load on the system increases with time, with the arrival of new requests. This cumulative loading enables us to simulate a heavily loaded system, which is of major interest from the load balancing point of view. We repeated the test runs 100 000 times for each algorithm (or variant) and averaged the results.

Figure 2 — Average percentage of unsatisfied users

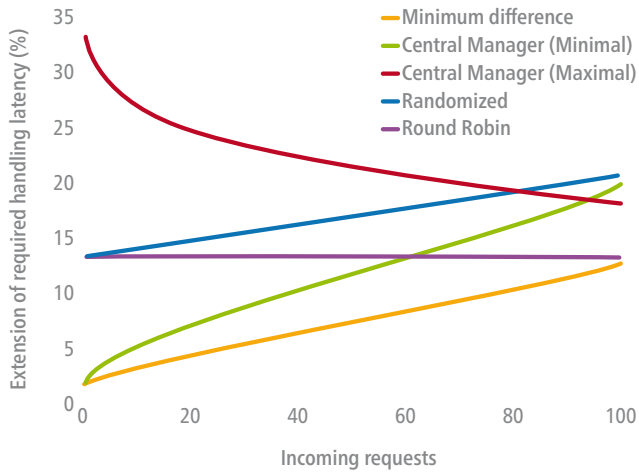


Figure 3 — Remaining ability of cluster to serve the requests

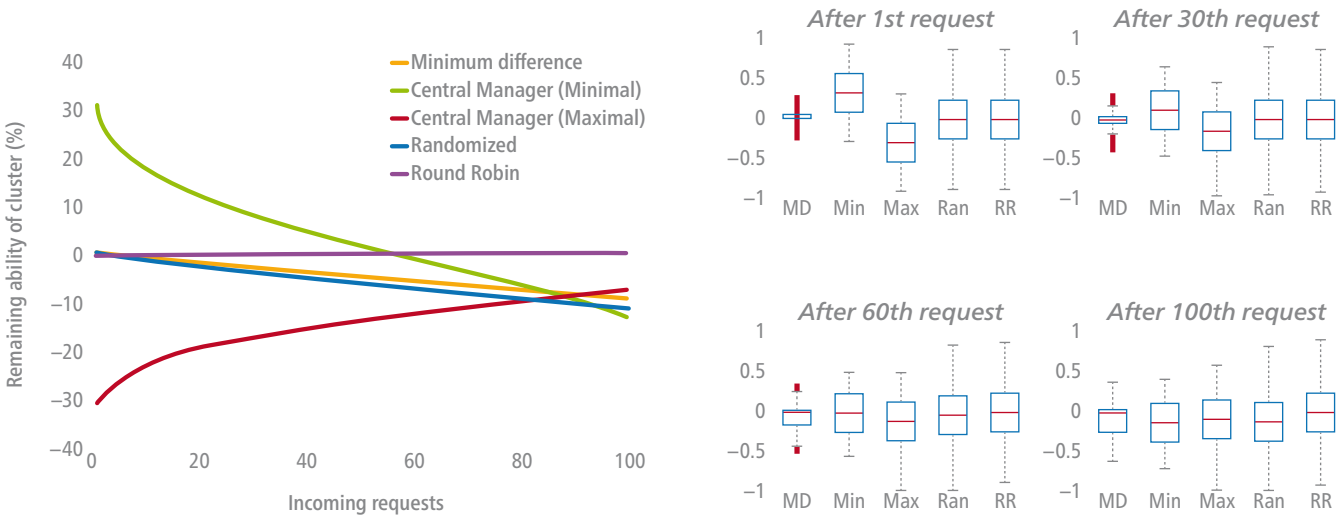


Figure 2 shows the ratio of requests which are not processed in time. In other words, the ratio can be expressed as a prolongation of the overall handling latency beyond the latency required by user. Our Minimum difference algorithm has the lowest unsatisfied ratio out of all the algorithms evaluated.

The remaining ability of a cluster to serve a request just after the request is assigned to the cluster is shown in Figure 3 (left-hand side). The remaining ability expresses the amount of resources available after the allocation of the resources to fulfil the request. Negative remaining ability means that the request cannot be processed in time. The proposed new Minimum difference algorithm performs reasonably well, exceeding the time requirements in only 10 per cent of cases for a fully loaded system. Note that a positive remaining ability to undertake computations when just a low number of requests have arrived does not imply any advantage for users. On the contrary, a highly positive residual ability indicates the inefficient allocation of resources to the lightly loaded clusters. The consequence of this is that there will be no available clusters for highly demanding requests later on, when the system becomes more heavily loaded. This can be seen on the right-hand side of Figure 3, where the remaining ability of Central Manager (Minimal) becomes the worst out of all the algorithms when the number of incoming requests is close to 100, despite the positive remaining ability when the system is less loaded. Out of all the algorithms that we compared, our proposed Minimum difference algorithm provides the most equivalent (and thus the most fair) satisfaction to all users.

About the authors

Michal Vondra *is a PhD student at the Department of Telecommunications Engineering, Faculty of Electrical Engineering, Czech Technical University in Prague, Czech Republic. He obtained his bachelor's and master's degrees in 2008 and 2010, respectively, at the same faculty. His research focuses primarily on mobility management, such as handover mechanisms and neighbour cell lists in networks with small cells. His field of research also includes load balancing in mobile cloud computing and vehicular ad hoc networks.*

Zdenek Becvar *received his MSc and PhD in Telecommunications Engineering at the Czech Technical University in Prague, Czech Republic, in 2005 and 2010, respectively. Currently, he is Assistant Professor at the Department of Telecommunications Engineering at the same university. From 2006 to 2007, he was involved in research at the Sitronics research and development centre in Prague and the Vodafone research and development centre at the Czech Technical University in Prague. Since 2007, he has been continuously involved in the FP6 and FP7 projects founded by the European Commission. He represents the Czech Technical University in Prague in the 3GPP and ETSI standardization bodies. He is a member of more than 15 conference committees and he has published more than 50 papers in international conferences or journals. His research interests cover future mobile networks with a focus on optimization of radio resource management and mobility procedures, mobile cloud computing and architecture of mobile networks.*

Deep programmability in communication infrastructure

A closer look at software-defined networking and network functions virtualization

Akihiro Nakao

Associate Professor at the University of Tokyo, Japan

In recent years, the Internet has had to cope with changes in our communication patterns and usage practices. The growing popularity of smartphones, the interest in small wearable gadgets such as smart-glasses and smart-watches, the existence of billions of sensors, and the move towards cloud data centres and cloud computing have put unprecedented strains on the network architecture. In Japan, communication failures resulting from rapid increases in smartphone traffic have even led the ministry concerned to issue administrative guidance to major mobile carriers. Also, a plethora of cybersecurity problems are reported every day, such as denial of service, spamming, phishing, spoofing, network security breaches, and invasion of privacy often caused by botnets (a large number of networked computers and smartphones compromised and controlled by adversaries). Meanwhile, cloud-based distribution of large content is increasing network traffic.

The potential benefits of the Internet — which has been described as the infrastructure for anyone to transmit and receive any data freely anywhere to anyone — may be lost because of changing use and growing misuse. This concern highlights the fragile nature of a fixed and inflexible infrastructure.

Our research group — the Interfaculty Initiative in Information Studies, which works under the auspices of the Graduate School of Interdisciplinary Information Studies at the University of Tokyo — believes that one of the most effective solutions to the emerging challenges is to enable deep programmability within the future communication and computing infrastructure. The group primarily conducts research on future networking and computing infrastructure and applications. Our work especially focuses on flexible and deeply programmable communication infrastructure, such as software-defined networking, network functions virtualization, and network virtualization. Our approach is not just bottom-up, building deeply programmable infrastructure and

enabling new applications on top, but also top-down, imagining applications that do not exist today and that would benefit our society, and allowing those applications to drive our design of programmable communication infrastructure — that is, application-driven programmable networking.

Software-defined networking and network functions virtualization

Deep programmability refers to the whole range of programmability, including network applications, control-plane elements and data-plane elements. Software-defined networking and network functions virtualization are the technologies included in this conceptually wide area of studies of programmable infrastructure.

Software-defined networking defines publicly available open interfaces between the control plane and the data plane. It enables software programs to monitor and manage resources, operate and manage networks, control access, and so on. The primary benefit of software-defined networking is to reduce operational expenses (by automating operations, administration and management) and capital expenses (by bringing openness to network equipment). Work in the area of software-defined networking is currently attempting to enable the programmability of network applications and control-plane elements, but there seems to be little interest in the programmability of data-plane elements, thus limiting programmability and the use of computing within the network.

Enabling deep programmability lifts the limitations imposed by current software-defined networking practices, and makes it possible to realize a deeply programmable network that fully supports the whole range of programmability mentioned above.

We believe that software-defined networking should be extended to support the programmability of data-plane elements, so that new data-plane functionalities can be plugged in and unplugged flexibly.

Extending software-defined networking to enable simple programmability for data-plane functionalities and to support the capability of defining or redefining interfaces for data-plane functionalities, along with publishing those interfaces to control-plane elements and network applications, also further reduces operational

and capital expenses, because we can add or remove or modify data-plane functionality by simple programming. Thus, we can reduce the complexity of maintenance, and decrease the life-cycle costs often observed in hardware-based inflexible data-plane elements. Simple modification to interfaces to access new data-plane functionalities enhances the capabilities and improves the efficiency of network applications and control-plane elements.

Network functions virtualization aims at implementing network functions (for example, network appliances) as software programs on virtual machines on high-end standard servers and the switches connecting them. The primary benefits are to reduce power and space requirements, and decrease the complexity of the maintenance and life-cycle of hardware-based network appliances. However, network functions virtualization currently focuses on implementing existing network appliances, rather than supporting new protocol handling.

In our laboratory, we consider that deeply programmable infrastructure extends the concepts of software-defined networking and network functions virtualization in both wired and wireless networking. So far, we have developed two kinds of infrastructure technologies — FLARE and WiVi.

FLARE — node architecture

FLARE is a node architecture that enables open deep programmability within a network. FLARE introduces an isolated programming environment called a "sliver" — a set of computation, storage and linked bandwidth resources. It supports multiple slivers by means of cutting-edge virtualization technologies (such as light weight resource containers and full virtualization hypervisor). Each FLARE node has a control module called "node manager", which dynamically installs or removes slivers, and a programmable classification engine called "packet slicer", which quickly scans packets and multiplexes or demultiplexes them from or to slivers.

A central control node called "FLARE central" remotely manages multiple FLARE nodes and creates or removes or assigns slivers for sliver programmers, on demand, communicating with each node manager to allow programmers to access their own sliver and inject their programs. The FLARE architecture also enables advanced network virtualization.

The FLARE node architecture can be applied to wired network switches and wireless network access points. We plan to work on a high-end version of FLARE nodes, which we expect to be deployed in cloud data centre environments.

A variety of applications and network services can be enabled through FLARE nodes. For the sake of brevity, we mention only the following.

First, FLARE's design enables multiple software-defined networking control using slivers in an isolated manner. Thus, we may apply software-defined networking control to different flow spaces. The benefit is that we can instantly upgrade or downgrade switching for a flow space, enabling incremental upgrades while maintaining compatibility with old technologies.

Second, FLARE supports deeply programmable software-defined networking solutions. This feature makes it possible to apply traffic engineering to a specific device or application or piece of content. That is, FLARE provides control and packet processing according to application context.

Third, as an example of deep programmability, FLARE can define switching using layer-2 protocols. For example, FLARE makes it possible to extend MAC addresses from 48 bits to 128 bits, not only staving off MAC address exhaustion, but also supporting a large number of tenants in data centre networks while also maintaining transparency for Internet protocol applications.

WiVi — programmable Wi-Fi access point infrastructure

Another example of deeply programmable infrastructure is WiVi. This programmable (software-defined) Wi-Fi access point infrastructure allows us to execute programs in multiple independent programming environments — slivers — sharing a single physical radio device.

Each program in the isolated programming environment is exposed to a logical wireless device. This allows you to run arbitrary (different) access point logics such as 802.11 Wi-Fi access services and 802.11 mesh protocols concurrently, as well as data processing, for instance, data compression, transcoding and caching. We believe that data-plane programmability at Wi-Fi access points enables a number of interesting first-mile and last-mile applications, especially for offloading computation and storage from smartphones to the nearest access points.

One such example application is BeaconCast, the technology we have developed for enabling concurrent information dissemination to a large number of receivers without authentication. This works by conveying data piggy-backed over beacon control frames. Multiple beacon frames are combined to convey information, so that data of several hundreds of kilobytes may be disseminated within several seconds. On a single WiVi access point, we can enable BeaconCast in one sliver, while maintaining a regular public Internet access service such as a hot spot service in the other sliver.

The benefits of this capability of running multiple independent services in an isolated manner are many. First, we should be able to accommodate several different Internet service providers running their own services using an isolated set of resources without interference among them. Second, we can accommodate several network services together that require different environments, for example conflicting prerequisite libraries that cannot be run in a single operating system environment. Third, we can instantly upgrade or downgrade (for fall-back purposes) a network service and also operate different versions of the same service concurrently. This allows us to provide support for users with different (possibly outdated) versions of client software.

Clean-slate thinking

Deeply programmable network research encourages clean-slate thinking. It stimulates ideas about redesigning the network in order to overcome the limitations inherent in traditional networking.

We are striving to define a future network that will be able to flexibly and dynamically resolve the kinds of problems that we see constantly cropping up in the current communications infrastructure.

About the author

Akihiro Nakao received his BS in Physics in 1991 and ME in information engineering in 1994, both from the University of Tokyo. He was a researcher at the IBM Yamato Laboratory, the Tokyo Research Laboratory and at IBM Texas Austin from 1994 to 2005. He received his MS in 2001 and PhD in 2005 in computer science, both from Princeton University, United States. Since 2005 he has been teaching at the Interfaculty Initiative in Information Studies, Graduate School of Interdisciplinary Information Studies, University of Tokyo, as an associate professor of applied computer science.

Graduate programme for ICT global leaders

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Globalization and the knowledge-based society call for industry leaders who are both highly intellectual and possess advanced technical knowledge in the field of information and communication technologies (ICT). This implies a need for leadership training so that the industrial sector can meet the expectations of the global community. A graduate doctoral programme offers a career path to industrial leadership.

The Japan Advanced Institute of Science and Technology has established such a programme. The programme aims to expand technical knowledge, broaden cultural vision, hone professionalism and communication skills, and foster internationalism. The Japan Advanced Institute of Science and Technology strives to train leaders who will play an active role in various sectors of society — both inside and outside the country.

Japan Advanced Institute of Science and Technology

The Japan Advanced Institute of Science and Technology was established in 1990 as Japan's first solely graduate institute. Its purpose is to advance science and technology, as well as to train and educate future scientists and engineers.

Developing science and technology to open up a new world requires outstanding young minds with intellectual

curiosity, comprehensive knowledge and a profound interest in advanced research. The Institute's educational system is designed to respond to these requirements. Its graduates (4753 with master's degrees and 722 with doctorates) are playing active roles in both the industrial and the academic worlds.

Before the Japan Advanced Institute of Science and Technology became an academic member of ITU's Telecommunication Standardization Sector (ITU–T) in 2013, many of its professors played an active part in ITU–T's standardization activities. The Institute's graduate programme for ICT global leaders includes a special focus on the field of international standardization. In particular, the objective is to train leaders who can play an active role in the technical committees of ITU, the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), among others, in order to advance international standardization in the ICT sector.

The programme

Japan Advanced Institute of Science and Technology's five-year doctoral programme is designed for those students who — at the beginning of their master's course — decide that they will continue their studies up to the doctoral level. Thus, there is a continuous educational programme from the beginning of the master's course through to the end of the doctoral course.

In March 2013, the special graduate programme for ICT global leaders was added to the master's and doctoral courses already offered by the Institute. The graduate programme for ICT global leaders comprises a master's course and doctoral course.

At the master's level, a course on "Leaders basic training" aims to cultivate the necessary skills and abilities for a future doctoral dissertation. The course curriculum ranges from introductory courses to advanced courses, and includes liberal arts courses, communications courses and career-enhancing courses. In the second year of the masters, students must present a final thesis based on a project report. The thesis is judged according to the accepted global standard for a master's qualification. The final examination, however, goes beyond looking at whether the students have mastered the basic skills and abilities necessary to produce a successful doctoral

dissertation. An assessment is also made of whether the students have the intellectual quality, advanced technical knowledge and level of skills that are required for them to be international society leaders.

At the doctoral level, the objective of the "Leaders special training" course is to train the students to be world leaders in ICT in various sectors of society. In the context of their main research topic, students are trained in research planning and management. As future research and development leaders, the students must be able to exchange opinions with oversea researchers. To this end, the programme actively promotes study abroad and internships (in particular, at overseas companies).

Excellent foreign students are allowed to participate in the programme. This indirectly gives the students a global viewpoint and starts to build an international network for future collaboration. It also enhances communication skills, including linguistic skills. Personal mentors from various fields of industry in Japan and abroad are engaged to advise and guide the students, and to inculcate leadership awareness.

The students receive English language training in their specialized fields, enabling them to understand, communicate and debate the essence of their chosen topics in English. To complete the doctoral programme, the students must submit their doctoral dissertation in English and take their final oral examination in English.

About the authors

Yoh Somemura *received his BE, ME and PhD degrees in applied physics from Waseda University, Tokyo, in 1988, 1990 and 1995, respectively. He joined NTT LSI Laboratories in 1990 and worked on the development of micro-fabrication technology. Since moving to NTT Energy and Environment Systems Laboratories in 2006, he has been engaged in promoting environmental management in the NTT Group. Until March 2009, he was a Vice-Chairman of the ITU Telecommunication Standardization Sector (ITU–T) Focus Group on ICT and Climate Change. Having been appointed as Research Professor at the Japan Advanced Institute of Science and Technology, he is currently engaged in training global leaders so that they can play an active part in international society in the field of information and communication technologies.*

Azman Osman Lim *received his PhD degree in communications and computer engineering from Kyoto University, Japan, in 2005. From 2005 to 2009, he was an expert researcher at the National Institute of Information and Communications Technology, Japan. Since 2009, he has been working at the Japan Advanced Institute of Science and Technology as an associate professor. During 2005–2008 he participated in the standardization activities of IEEE802.11s Mesh Networking. In 2006, he took part in the standardization activities of Japan's Telecommunication Technology Committee (TTC) in regard to next-generation home networks.*

Yasuo Tan *received his PhD from Tokyo Institute of Technology in 1993. He joined the Japan Advanced Institute of Science and Technology in the same year, and has been Professor of Information Science since 1997. He is also an invited advisor of Japan's National Institute of Information and Communication Technology. He is interested in home networking technologies and he has contributed to standardization activities in this field, mainly in the ITU Telecommunication Standardization Sector, the International Electrotechnical Commission and TTC.*

Collaborate with ITU–T to advance standards education worldwide!

ITU–T and academia join forces

Recognizing that students of today will become the experts driving the standardization processes of tomorrow, Malcolm Johnson, Director of the ITU Telecommunication Standardization Bureau (TSB) established the Ad Hoc Group on Standards Education. The group's aim is to investigate academia's approach to standardization in the field of information and communication technologies (ICT), with a view to increasing the weight assigned to this subject in academic curricula. The group, which was set up in 2012, has also started to identify actions that ITU's Telecommunication Standardization Sector (ITU–T) can take that would aid its academic membership in this endeavour.

The secretariat of the group invites universities and experts in the field to take the lead or participate in any of the actions identified so far. The work plan for the group includes collecting information on standardization courses currently offered worldwide; identifying leading academic institutions interested in education about standardization, and exploring collaboration efforts; detecting any gaps in standards education; developing a standards tutorial and finding academic members that will contribute to it; and setting out a strategy for the development of materials for education about standardization, as well as identifying common requirements.

The results of all the actions taken by the leaders in these areas up to May 2014 will be presented at the group's next meeting, which will be held in conjunction with the ITU Kaleidoscope academic conference 2014, on 3–5 June, in Saint Petersburg, Russian Federation. Practical ideas contributed to the Ad Hoc Group on Standards Education will be published in ITU News and the Journal of ICT standardization.

The group includes representatives of ITU–T, academia and other standards-development organizations interested in collaborating to advance standards education worldwide. Participation is open to all interested parties, including non-members of ITU, free of charge.

In the context of the activities of the Ad Hoc Group on Standards Education, the term "standards education" relates not to technology-focused topics, but rather to education on the importance of standards to the ICT sector and, by extension, to the operation of businesses and economies at large. ICT today underpin almost all commercial activity, and it is essential that we familiarize students with ICT standards-development processes, how standards strategies are planned and business case studies demonstrating the importance of international standards to industry.

For more information, including terms of reference and details on how to subscribe to the mailing list (standardsedu@lists.itu.int), please see the Ad Hoc Group on Standards Education's web page: http://www.itu.int/en/ITU-T/academia/Pages/stdsedu/default.aspx.

Keystone/Science Photo Library

Cybersecurity in the spotlight at ITU Telecom World 2013

This year, for the first time, there was a dedicated Cybersecurity Pavilion at ITU Telecom World. ITU's partners — ABI Research, Nuix, High Tech Bridge, The Cyber Guardian, Symantec, the Regional Cybersecurity Centre (RCC) and the International Multilateral Partnership Against Cyber Threats (IMPACT) — came together to showcase and disseminate information on cybersecurity-related activities that focus on ensuring a secure and safer digital environment.

Facilitating dialogue

The Cybersecurity Pavilion facilitated dialogue and discussion between participants from both the public and the private sector. The show floor session on "Building Cybersecurity Capabilities in the Developing World: Needs, Challenges, and the Role of Public-Private Partnerships" mainly focused on the lessons learned from ITU-IMPACT and its partners on how to enhance cybersecurity and move forward in helping developing countries to build robust cybersecurity capabilities while respecting fundamental values and the economic importance of the Internet.

During the session, ITU Secretary-General Dr Hamadoun I. Touré reviewed the achievements of ITU's Global Cybersecurity Agenda, and highlighted one of its main activities — the Child Online Protection initiative. The Secretary-General emphasized the need to "recognize the very real dangers being faced by children and young people online, who often find themselves in cyberspace alone and unprotected." He also stressed the importance of cooperation in providing successful protection.

E-Oman's participation in ITU Telecom World 2013 reflected a strong belief in the utility of being part of the ongoing technological revolution. It was an essential element in E-Oman's effort to keep up with change, understand and embrace it. Tasked to build cybersecurity capabilities, Oman's National Computer Emergency Readiness Team (OCERT) played an active role in the pavilion, discussing ideas, exchanging perspectives and taking the first steps towards building a new approach for the way forward. OCERT will showcase E-Oman's partnership with ITU and its achievements in cybersecurity. It also plans to create an interactive network with multiple stakeholders in order to foster a global culture of cybersecurity, as well as to highlight the regional centre's activities and services related to building confidence and security in the use of information and communication technologies.

High-Tech Bridge provides customers across the globe with information security services such as penetration testing, security auditing, computer crime investigation and web application security testing. Both business and governmental information services have become web-centric. Therefore, web applications have become vital to almost any public or private organization, but these applications can be dangerously weak links in the network security perimeter. Web application vulnerabilities are exploited by hackers more frequently than server or network vulnerabilities. High-Tech Bridge's long-standing penetration testing and computer forensics experience helps to safeguard security and maintain website availability compatibility with third-party resources.

The complexity of cyber risk is growing rapidly. Virtualization, cloud computing, and mobility are transforming the enterprise IT infrastructure, expanding it beyond the traditional boundaries of the data centre, and raising the potential attack surface for threats. To help clients in securing borderless enterprises, Symantec delivers measurable business value with a cyber-risk solution that is relevant to the ICT industry, and tailored to its requirements. Symantec is dedicated to providing cybersecurity strategies that allow its clients to defend the borderless enterprise.

The Cyber Guardian (TCG) is a private technology company originating in Australia with labs in Malaysia and the Philippines. TCG has developed a range of high level security systems for governments, Internet service providers and small to multinational corporations. The range includes sophisticated network security, threat management gateways and modern network filtering and reporting capabilities — all managed by the customer via central control panels. Child online protection remains a high priority and the TCG Child Online Protection system — designed for use by governments and Internet service providers — provides an entirely safe environment for children, without censoring content accessible to adults, or slowing down the network.

ABI Research, established in 1990, is a market intelligence company specializing in global technology markets. It blends quantitative forecasting and trend analysis to quantify the important markets of today, define the strategic technologies of tomorrow, and provide insight on how technology is adopted in vertical markets. ABI Research's clients rely on its services to uncover key market metrics and trends that are compiled through a combination of hundreds of comprehensive stakeholder interviews per year, technical intelligence from teardowns, years of collective market experience, vendor contributed data and end-user research.

The greater levels of skill, knowledge and tools that are now available to hackers call for countries' response forces to be similarly equipped. Nuix is working in partnership with ITU-IMPACT to build the forensic investigative capabilities of the United Nations Member States, in order to enhance their abilities to defend themselves against, and respond to, cyberthreats. Nuix Investigator software has the ability to deal with high case volumes, handle large data sets and support powerful investigative workflows. It can therefore highlight the key evidence fast and allow analysts to work across many cases. In addition, Nuix will support ITU-IMPACT with training sessions, and the development of procedures and software solutions.

The Child Online Protection initiative was one of the central topics discussed in the Cybersecurity Pavilion. At a session entitled "Child Online Protection: VISION BYND 2015", Dr Touré explained that "only by working together and joining forces can we ensure a safer and brighter online future for our children", reiterating that cyberthreats "can only be countered with collective resolve". The First Lady of Nigeria and ITU Child Online Protection Champion, Dame Patience Goodluck Jonathan, also called upon stakeholders to take practical steps to further national and domestic policies, programmes and educational initiatives to improve child online safety.

Showcasing achievements

The launch of the Global Cybersecurity Index (GCI) at the pavilion demonstrated the continuing success of ITU's Global Cybersecurity Agenda. The GCI is a project to rank the cybersecurity capabilities of countries in different regions, and it comprises one global index. "We are only as strong as our weakest link," said Dr Touré. "We can learn from the best practice of those countries at the top of the index and create a global culture of cooperation and support. We can't afford not to do this." Data from the first sample, the Arab region, were presented, with Oman ranking highest, followed by Morocco and Egypt.

In a workshop on security standards, participants were given an overview of ITU's "Standards on Security and Identity Management" and a detailed walkthrough of the various security standards developed by the Joint Coordination Activity on Child Online Protection, which works within ITU's Telecommunication Standardization Sector (ITU–T).

Demonstrating cooperation

ITU's Global Cybersecurity Agenda depends on partners' technical know-how and collaboration. At Nuix's demonstration, Rob Attoe, Senior Vice President of Nuix's Investigations Training and Services, compared traditional and host-based investigations. He also explained the techniques that are used to locate network artefacts, in order to retrieve connection data and historical information.

ITU celebrated its partnership with Trend Micro in the Cybersecurity Pavilion. Together, the two organizations will regularly distribute co-branded information to key influencers and audiences. This will benefit ITU's membership by providing the latest information on fighting cyberthreats globally. Dr Touré praised the collaboration, saying: "Trend Micro is supporting our vision by providing expertise and resources to help people avoid being victimized by criminal and irresponsible online behaviour."


ITU/V. Martin

Official Visits

During November 2013 courtesy visits were made to ITU Secretary-General Dr Hamadoun I. Touré by the following ministers, ambassadors to the United Nations Office and other international organizations in Geneva, and other important guests.

ITU headquarters


Vladislav Mladenović, Ambassador of Serbia and
Dr Hamadoun I. Touré, ITU Secretary-General


Mehmet Ferden Çarikçi,
Ambassador of Turkey


Aya Thiam Diallo,
Ambassador of Mali


William Francis,
Assistant Cabinet Secretary (Policy), Bermuda

Jüri Seilenthal,
Ambassador of Estonia

Professor Seang-Tae Kim,
SungKyunKwan University,
Republic of Korea

Moses Kouni Mosé,
Ambassador of the Solomon Islands

Mohammad Sabir Ismail, Ambassador of Iraq

ITU Telecom World 2013

Dr Ali Abbasov,
Azerbaijan's Minister of Communications and
Information Technologies

Lyonpo D.N. Dhungyel,
Bhutan's Minister of Information
and Communications

From left to right: N.K. Goyal, Vice Chairman, ITU-APT Foundation, India; Houlin Zhao, ITU Deputy Secretary-General; and Anil Prakash, Secretary General, ITU-APT Foundation, India

From left to right: John Davies, General Manager of the Intel World Ahead Program, Intel Corporation; Dr Hamadoun I. Touré, ITU Secretary-General; and Christoph Legutko, Global Public Policy CEE, Intel Corporation

Dr Masao Sakauchi, President of the National Institute of Information and Communications Technology (NICT), Japan

Ivo Ivanovski, Minister of Information Society and Administration of the Former Yugoslav Republic of Macedonia and Chairman of the World Telecommunication Policy Forum

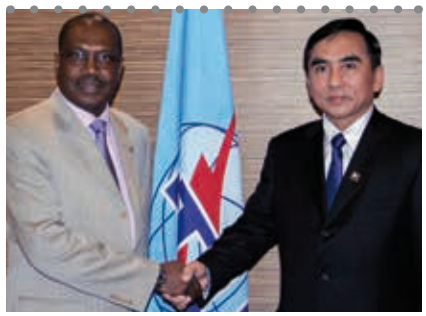
Veali Vagi, High Commissioner, Papau New Guinea

Lord Tu'ivakano, Prime Minister of Tonga

Lorin Ymeri, Cabinet Director, Albania's Ministry of Innovation and Publication Administration

Hesham Alaily, Executive President of Egypt's National Telecommunication Regulatory Authority (NTRA)

Victor H. Ossavou,
Advisor to the Minister responsible for quality and control of audio visual programmes, Gabon



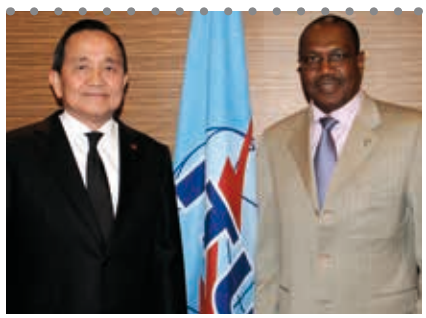
Than Thun Aung,
Director, Post and Telecommunications Department, MICT, Myanmar

His Excellency Sheikh Abdullah Bin Mohammed Bin Saud Al Thani, Chairman of the Board of Directors of Ooredoo (formerly Qtel Group), Qatar

From left to right: Fadi Morjanh, Director of the Government Computer Center of Palestine's Ministry of Telecommunications and Information Technology; Houlin Zhao, ITU Deputy Secretary-General; Dr Safa Nasser, Palestine's Minister of Telecommunications and Information Technology; and Mahmood Diwan, Director General of the Ministry of Telecommunications and Information Technology, Palestine

From left to right: Dr Hamadoun I. Touré, ITU Secretary-General; Jacquelynn Ruff, Vice President, International Public Policy and Regulatory Affairs, Verizon America; and Leslie Joseph Martinkovics, Director, International Public Policy and Regulatory Affairs, Verizon America

Hakon Bruaset Kjol,
Senior Vice President, Telenor Group



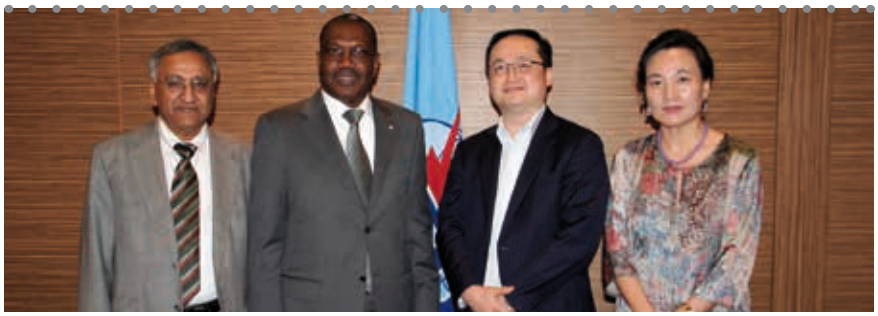
Thares Punsri,
Chairman of the National Broadcasting and Telecommunications Commission (NBTC), Thailand

Llewellyn M. Toulmin,
Strategic iGovernment Advisor, Government of Vanuatu

Richard C. Beaird,
Senior International Policy Advisor,
Wiley Rein LLP, United States

Bruno Nabagné Koné,
Côte d'Ivoire's Minister of Post and
Information and Communication Technologies

Tweesak Dheerakiatkumchorn,
Advisor to the Chairman of International
Multilateral Partnership Against Cyber
Threats (IMPACT)



From left to right: Srini Prasanna, Vice President, Asia Broadcast Satellite, Hong Kong (China); Dr Hamadoun I. Touré, ITU Secretary-General; Thomas Kyo Choi, Chief Executive Officer, Asia Broadcast Satellite, Hong Kong (China); and Dr Eun-Ju Kim, Director of ITU's Regional Office for Asia and the Pacific

Datuk Mohd Noor Amin,
Chairman of the International Multilateral
Partnership Against Cyber Threats (IMPACT)

From left to right: Jim Kent, Head of Investigation Services and CEO, Nuix, EMEA; Dr Hamadoun I. Touré, ITU Secretary-General; and Stuart Clarke, Director of Investigation Services, Nuix

From left to right: Franz Joseph G. Zichy, United States Department of State; Dr Hamadoun I. Touré, ITU Secretary-General; and Julie N. Zoller, Senior Deputy Coordinator, United States

Eng. Badar Ali Al-Salehi,
Director of Oman National CERT

Dr Mohamed Ibrahim Ahmed,
Secretary General of the Ministry
of Communication for Posts and
Telecommunications, Djibouti

Martine Condé,
President of the *Conseil National de la Communication* (CNC), Guinea

Abou Lo, Director General,
Autorité de Régulation des Télécommunications et des Postes (ARTP), Senegal

Rebecca Joshua Okwaci,
South Sudan's Minister of
Telecommunications and Postal Services

Dr Nongluck Phinainitisart,
President and Chief Commercial Officer,
Thaicom, Thailand

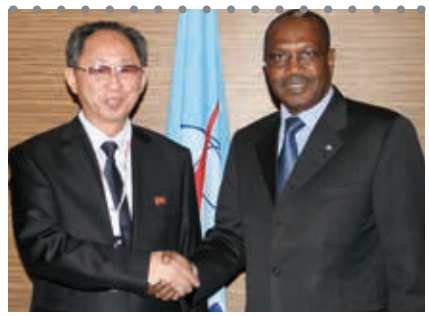
Max Thomas,
founder and CEO of The Cyber Guardian

Dr Masego Ayo Mpotokwane,
Chairman of the Board of Directors, Botswana
Communications Regulatory Authority

Jean-Pierre Bienaimé,
Chairman of the UMTS Forum, France

Rabindra N. Jha,
Deputy Director General (International Relations), Department of Telecommunications, India's Ministry of Communications and Information Technology

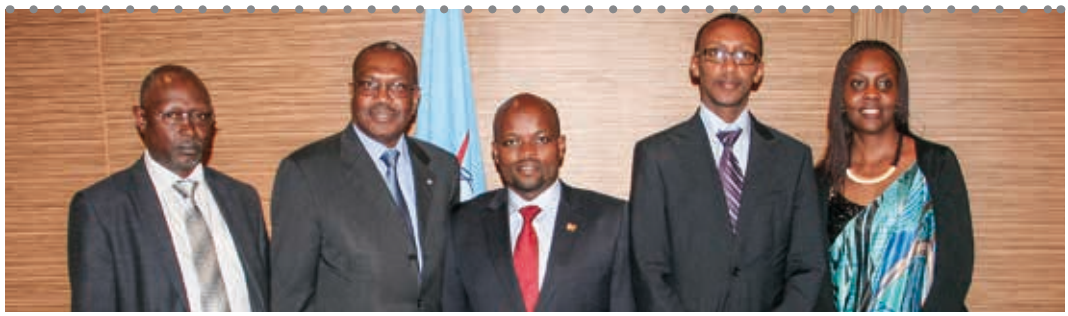
Senator Mutahi Kagwe EGH,
MP, Parliment of Kenya, Chairman of the Standing Committee on Education, Information and Technology



Chol Ho Sim,
Republic of Korea's Minister of Posts and Telecommunications

From left to right: Malgorzata Olszewska, Undersecretary of State, Poland's Ministry of Administration and Digitization; Houlin Zhao, ITU Deputy Secretary-General; and Magdalena Gaj, President of Poland's Office of Electronic Communications

Panjyi Kaunda MP,
Deputy Minister, Zambia's Ministry of Transport, Works, Supply and Communications



Dr Hamadoun I. Touré, ITU Secretary-General and Jean Philbert Nsengimana (centre), Rwanda's Minister of Youth and Information and Communication Technology with high level delegates

All photos are by Ivan Wood/ITU and Kitt Thammapalerd/ITU.

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ITU TELECOM WORLD '14

Doha, December