GTPRN June 2020 Newsletter

Welcome to the GTPRN June 2020 newsletter.

We have the privilege this issue to have several exclusive contributions for GTPRN by high profile telecom policy practitioners and academics.

The first of them is by Ambassador Grace Koh, the head of the US delegate to the WRC-19, on the U.S. mid-band spectrum policy. While some of you may attended her keynote speech at TPRC last year, I had the pleasure of observing her facilitating, enforcing, and leading the discussions in more than 30 issues in WRC-19 in a way that made the conference one of the most successful WRCs for the US and for the world, if I may say so.

We are also honored to include in this month newsletter, a kind contribution on one of the most important ITU-R study groups, Study Group 1 (SG1), by Eng. Wael Sayed, Chair of SG 1, and the Dean of WRC-19. Mr. Sayed is also the Head of Radio Spectrum Planning Sector at NTRA, and he successfully led the Egyptian delegate during WRC-19. One of the main reasons for inviting Mr. Sayed to this issue is to continue the discussion on 'interference management' we have raised last issue with highlighting the contribution of Dr Pierre De Vries with this regard. In fact, SG 1 is one of the few ITU-R SGs that addresses economic and regulatory aspects of spectrum management (e.g. pricing, auction), and in the last years, it has addressed 'interference management for stations that may operate under more than one radiocommunication service'.

Dr. David Reed has kindly sent us a non-exclusive list of research topics on spectrum management. Please share with Dr. Reed and the GTPRN community your views on how we can cooperate to address these topics. You can do that by contacting us (news@gtprn.org) or by commenting directly on the post named 'Research Agenda for Spectrum Management' on our website. Dr. David Reed under the leadership of Prof. Dale Hatfield has been providing a unique and must-

attend course on telecom policy each year in Colorado 'Managing Effectively in the Changing Telecommunications Environment'.

Policy Tracker, the spectrum management newsletter, has conducted last week an interesting webinar entitled 'New Thinking in Spectrum Auctions', and Martin Sims, the managing director, has kindly agreed to share with the GTPRN community the presentations at the links below.

Martin Sims, PolicyTracker:
Scene setter
Professor Gerard Pogorel:
Spectrum: What's our emergency?
Professor Martin Cave:
How many policy objectives can spectrum auctions achieve at once?
Professor Antonio Nicita, AGCOM:
Information, spectrum and information over spectrum
Professor Erik Bohlin:
Innovation, Investment and Regulation Trade-offs in 5G Market Design

PolicyTracker's next Webinar will be on spectrum sharing and will be held on 17th June. If you are not a PolicyTracker subscriber, you can still receive an invitation to all future webinars via joining their free Weekly Spectrum Briefing mailing list.

With respect to telecom policy conferences, TPRC-48 dates have been postponed to February 19-20, 2021. More details could be found here. PTC-21, one of our favorite conferences, are confirmed until now to be in the period of 17-20 January 2021. The deadline for paper abstracts is on 10th of July 2020. Please visit https://www.ptc.org to learn more. Another relative conference is the IEEE / ITU International Conference on 'Artificial Intelligence for Good (AI4G 2020)'. The AI4G 2020 conference will be held in conjunction with the ITU AI for Good Global Summit. Paper submission due is on 29th June 2020. More information can be found here. Some other interesting conferences will be virtual this year.

For instance, ECIS 2020, PACIS 2020 and AMCIS 2020 have joined to offer all three conferences as one package. 2020 AIS virtual conference series

With respect to telecom policy journals, kindly take a look on the July issue of Telecommunications Policy 'Artificial intelligence, economy and society'. You can take a look on the index to the issue with links to an abstract for each article here. The September 2020 issue (Volume 52) of Telematics and Informatics is also now available online for subscribers here.

We have added a section in this newsletter issue for job and research opportunities at Chalmers University of Technology, Ericsson, Palladium, NSF, and Microsoft. Please share them with other interested colleagues and students.

The ITU has launched new study paper on broadband and connectivity solutions for rural and remote areas, and it has made 4 key recommendations for regulators and policymakers namely, ease regulatory requirements for community network operators, promote tax and customs duty breaks to enable more investment in infrastructure, enhance transparency and ease of doing business to encourage investment in infrastructure, and focus on complementary access networks that service underserved markets. More information can be found here.

The ITU has also issued new statistical report namely 'Measuring Digital Development: ICT Price Trends 2019' and the latest global analysis of prices for mobile-voice, mobile-data and fixed-broadband services suggests that affordability is not the only barrier to Internet uptake. More information can be found here.

Since COVID-19 has been dominant theme and contact tracking or tracking applications dominated interest. ScanForm was built by QED (https://qed.ai) for malaria/HIV/TB epidemiological surveillance in Kenya, and it can be used for

rapid COVID-19 case reporting in accordance with WHO protocols. It enables paper forms to be transcribed with a single smartphone photo. Read more here.

Indian government has announced opening the source code of its coronavirus tracking app, Aarogya Setu, for scrutiny by the developer community. See source code.

We also came across this interesting working paper 'How is COVID-19 affecting scientists?'

Slum and Rural Health Initiative have developed behavioural change communication messages on prevention of coronavirus in form of easy-to-read infographics in over 70 local languages which is available at www.tinyurl.com/stopcovid. You can collaborate with them or supporting them to do more on this project. As a registered NGO they are open to partnership. You may contact them via miracle.adesina@srhin.org

Take care, stay safe and well.

Mohamed El-Moghazi, Ayushi Tandon

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Updates on U.S. Mid-Band Spectrum Policy

Grace Koh
Former U.S. Ambassador and Representative to World
Radiocommunication Conference 2019

Mid-band spectrum (*i.e.*, spectrum between 3 and 24 GHz) is considered critical to the rollout of a robust 5G network, and most attractive to the mobile network operators is the range between 3 and 6 GHz. Often called the "sweet spot" of 5G spectrum, the frequencies are high enough to deliver fast data rates but also low enough to cover larger areas than millimeterwave spectrum. The premier wireless industry association, GSMA, notes that operators should have access to at least 80-100 megahertz of spectrum in the mid-band range, noting that 3.3-3.8 GHz appear to the bands favored by most commercial operators.

But COVID-19 has added an additional layer of pressure to the thorny task of balancing spectrum assignments. For one, it has added a level of urgency to the debate, as the pandemic has forced virtualization of many aspects of our daily lives – work, education, medicine, social interactions. Network demand for some applications increased as much as 200% in the United States during the month of March, applying a stress test, as some experts have called it, to the broadband industry. Governments are contemplating legislation and funding to help stimulate an economic recovery, including covering the gaps in the broadband networks. Many policymakers have looked to the promise of ubiquity, reliability, and security of 5G networks, but numerous questions continue to dog policymakers as they consider how to get to 5G quickly. In the United States, lawmakers are considering funding for research, data collection, and deployment, but competing concerns will continue to arise, also pushed by COVID's effects. The pandemic has exposed and made clear the choices struck between resiliency and efficiency. These choices and other considerations in managing the COVID-19 will affect the timeline for the United States government's efforts to put mid-band spectrum into the hands of commercial mobile network operators (MNOs).

In the United States, the debate over mid-band spectrum exemplifies this process of assessing priorities, as incumbents seek to protect their valuable services and MNOs seek to bring the promise of 5G. The domestic discussions over mid-band assignments for 5G are certainly intense in the United States. The United States is currently taking three approaches to the mid-band spectrum sought by the commercial mobile network operators. The current on spectrum bands 3.7-4.2 (the C band), 3.55-3.7 GHz (the Citizens Broadband Radio Service band or CBRS band), and spectrum used by primarily the Department of Defense in 3.1-3.55 GHz.

In the C-band, regulators are proposing full relocation and exclusive licenses of commercial spectrum currently allocated to satellite operators who currently use this band for to beam content to video and audio broadcasters, cable systems, and other content distributors. Relocation and exclusive licensing is the approach preferred by the mobile network industry. The Federal Communications Commission (FCC) has struck a deal, in which satellite operators are expected to relocate from the lower portion of the band to 4.0-4.2 GHz. Relocation will require launches of new satellites and filters for earth stations generating costs of up to $9.7 billion. Those costs would be covered by the proceeds from the auction, which would make 280 Megahertz of spectrum available to mobile network operators. The FCC Chairman has proposed that the auction begin December 8. Under the timeline, the spectrum must be cleared by December 5, 2025, though the regulations provide incentives for earlier relocation. Both Intelsat and SES, the two major incumbents in the spectrum, have agreed to the timeline and plan established by the FCC.

Intelsat also reminded the FCC that the COVID-19 pandemic will also affect the timeline for relocation. The pandemic may impact the availability of physical crews, equipment vendors, and permitting entities. As such, Intelsat recommended a waiver process to accommodate. Several smaller satellite companies have filed for legal review of the FCC order, but experts do not believe that a stay of the FCC order is likely.

In the CBRS band, the FCC established a hybrid sharing and exclusive license system, consisting of three tiers of access and authorization framework. Certain government users and fixed satellite services will have Tier 1 access, which protects them from harmful interference from any other user. The FCC then plans to allow Tier 2 users to have Priority Access Licenses (PAL), which will ensure exclusive use within a small geographic area. The small geographic area allows for smaller private networks that might support industrial control systems within a manufacturing plant or electric grid. The FCC expects to auction PALs at the end of June. These Tier 2 users may not interfere with Tier 1 users and must accept interference from Tier 1 users. Tier 3 users, or General Authorized Access users, may use the spectrum in compliance with the rules and must accept interference from any other users. Mobile network operators prefer exclusive licenses and larger geographic areas, but the system of shared access offers faster access to the spectrum.

Resistance to the auction for PAL licenses came from quarters arguing that CBRS provided broadband coverage in the rural areas through fixed wireless services. At least one large cable company in the United States has experimented with filling out its coverage using fixed wireless over CBRS spectrum. However, concerns regarding resiliency or coverage in the wireless areas appear to have

been mitigated by the promise of MNOs using that spectrum to build stronger networks. The auction is expected to commence on June 25; rules have been established, and it does not appear that the pandemic will impact the timeline or the expectations for the auction.

As for the remaining spectrum band, the United States government continues to discuss whether and how to repurpose that spectrum, which is largely assigned to use by the Department of Defense. Congress directed the National Telecommunications and Information Administration (NTIA) to study the feasibility of allowing licensed and/or unlicensed shared access to some or all of 3.1-3.55 GHz and submit a report by March 23, 2020. That report remains forthcoming though NTIA has issued a study indicating that time-based sharing with certain military radars may be feasible in the 3.45-3.55 GHz band.

NTIA has issued a document outlining the considerations and guidance for its review; the guidance document notes that the 3.1-3.55 GHz band supports a significant number of services operated by the Department of Energy, Department of Energy, Department of Homeland Security, the Air Force, the Army, the Navy, the Marine Corps, and the Department of Commerce. At this point, the discussion on repurposing this band remains behind closed doors, but the private sector continues to push for repurposing of spectrum through the press and quiet lobbying. The U.S. Department of Defense has put up strong resistance to the notion of repurposing the spectrum for exclusive licenses to MNOs but has noted that spectrum sharing frameworks can potentially work. The Ligado example may prove instructive on how this debate plays out. While Ligado's assignment involves commercial and shared spectrum, the resistance from government agencies – Departments of Defense and Transportation – has become very public, with the agencies seeking assistance from Congress.

These competing priorities come to bear more heavily in spectrum policy, as the governments consider how best to weather the pandemic. While the necessity of strong broadband networks – as well as the promise of 5G networks – has become very apparent, emergency preparedness is also top of mind for the policymakers.

One additional thought on the impact of current domestic mid-band discussions on the World Radiocommunication Conference 2023 (WRC-23) item on mid-band spectrum identification for 5G.

Due to the work already completed during WRC-15, administrations are already well on their way to assigning mid-band spectrum to 5G services. One analysis finds that an average of 382 megahertz of mid-band spectrum will assigned to 5G use by the end of this year in most administrations, before WRC-23 established further regulations for mid-band identification for 5G. In fact, 5G deployments

will be more than experimental by the time WRC-23 rolls around. Operators in Australia, China, Germany, Italy, Qatar, Spain, South Korea, the United Kingdom, among others, have launched 5G networks using mid-band spectrum.

This could mean that most of the battles over the assignment of mid-band frequencies will have occurred domestically before WRC-23, hopefully avoiding some of the more contentious discussions at the Conference. At the very least, the data gathered from real world deployment could have the effect of disciplining the work conducted in the ITU-R study groups. Or at least one can hope.

Grace Koh was most recently the U.S. Ambassador to the International Telecommunication Union's World Radiocommunication Conference 2019 in Sharm El Sheikh, Egypt, where she led the 125-member delegation in negotiating successful outcomes for U.S. spectrum and satellite policy. Before representing the United States at WRC-19, Ms. Koh was a partner in the Telecom Law Group at DLA Piper LLC, where she advised clients on regulatory and congressional issues on unmanned aerial vehicles, merger, Universal Service Fund and other matters. She came to DLA Piper LLC after serving as Special Assistant to the President for Technology, Telecom, and Cyber-Security Policy. In this role, she advised the President and other senior White House staff on all matters pertaining to technology policy. Koh previously served as Deputy Chief Counsel to the Subcommittee on Communications and Technology of the Energy and Commerce Committee in the U.S. House of Representatives. Her primary role was to advise the chairmen and committee members on policy and legal issues arising in the telecommunications and technology sectors. She was previously Policy Counsel at Cox Enterprises, Inc.'s Public Policy Office, working on technology policies affecting the enterprise's Internet, cable, and broadcast properties. Koh came to Cox Enterprises after working in the communications group at Willkie Farr & Gallagher LLP. She holds a B.A. from Yale University and a J.D. from the University of Pennsylvania Law School.

Both industry and government stakeholders respect her leadership, fairness, and collegiality. As a 15-year veteran of Washington, D.C., Ms. Koh has earned a reputation for substantive regulatory expertise as well as strategic political advice on effecting change at the Administration and in Congress.

Study Group 1
Radiocommunication Sector of ITU
Wael Sayed
Chair of ITU-R SG 1

The radio spectrum and satellite orbits are two limited natural resources which are in increasing demand from a wide-range and growing number of services such as fixed, mobile, broadcasting, amateur, space research, emergency telecommunications, meteorology, global positioning systems, environmental monitoring and safety of life communication services. The Radio Sector of International Telecommunication Union (ITU-R) plays a vital role in the global management of these two important resources. This role of ITU-R wouldn't be played without the great contributions of its study groups. This article will enlighten the role of one of these groups which is concerned of radio spectrum management and known among the specialists all over the world as ITU-R SG1.

The main objective of ITU-R SG1 is to set principles, techniques, general principles sharing, spectrum monitoring, long-term strategies for spectrum utilization, economic approaches and automated techniques in the field of radio spectrum management. In addition, Study Group 1 is working closely with relevant study groups within ITU Telecommunication Standardization Sector of ITU and Telecommunication Development Sector (ITU-D), as well as with the ITU Telecommunication Development Bureau (BDT) to assist developing countries in fulfilling their national spectrum management functions. Radio spectrum management is the combination of technical and administrative procedures necessary to ensure the efficient utilization of the radio spectrum by all radiocommunication services defined in the ITU Radio Regulations and the operation of radio systems, without causing harmful interference.

ITU-R SG1 has three working parties that are specialized in three working areas. WP1A which is concerning in spectrum engineering techniques which generally include unwanted emissions, frequency tolerance, technical aspects of sharing, computer programs, technical definitions, Earth-station coordination areas and technical spectrum efficiency. WP1A currently has some topics under its study that include wireless power transmission, EMC-related interference and coexistence of wired telecommunication with radiocommunication systems, including aggregation effect and the egress of radiated interference from buildings, definition of the spectral properties of transmitter emissions, impact on radiocommunication systems from wireless and wired data transmission technologies used for the support of power grid management systems, technical and operational characteristics of the active services operating in the range 275-3 000 GHz, characteristics for use of visible light for broadband communications, general principles and methods for sharing between radiocommunication services

or between radio stations and characteristics of the unwanted emissions in the out-of-band and spurious domains for digital modulation technology used in broadband communication systems. Also, WP1A was involved in preparation for some topics for WRC-19 such as identification of some frequency bands for the usage for the land-mobile and fixed services applications operating in the frequency range 275-450 GHz, while maintaining protection of the passive services. Working Party 1A is engaged in preparation for WRC-27 towards a spectrum allocation to the radiolocation service in the frequency band 231.5-275 GHz and an identification for radiolocation applications in the frequency range 275-700 GHz.

The second working party of ITU-R SG1 is WP1B which is focusing on spectrum management methodologies and economic strategies. Special interest is given to national spectrum management organization, national and international regulatory framework, flexible allocations and long-term strategies for planning. Its current study topics include long-term strategies for spectrum utilization, alternative methods of national spectrum management, spectrum redeployment as a method of national spectrum management, innovative regulatory tools for shared use of spectrum, economics aspects on spectrum management, assessment of spectrum efficiency and economic value, methodologies for assessing or predicting spectrum availability, harmonization for short-range devices and implementation and use of cognitive radio systems. Amongst those items on which Working Party 1B was engaged in preparation for WRC-19 were the studies on wireless power transmission (WPT) for electric vehicles in addition to assisting administrations in the management of unauthorized operation of earth station terminals. Working Party 1B is engaged in preparation for WRC-23 on topics related to space weather sensors, to the use of IMT systems for fixed wireless broadband, and to the protection of stations of the aeronautical and maritime mobile services located in international airspace and waters from other stations located within national territories and using the frequency band 4800-4990 MHz.

Finally, WP1C which is specialized in spectrum monitoring is working on the development of techniques for observing the use of the spectrum, measurements techniques, inspection of radio stations, identification of emissions and location of interference sources. Currently, its study topics include: methods and techniques used in space radio monitoring, spectrum monitoring evolution (e.g. use of drones and small satellites), direction finding, electromagnetic field measurements to assess human exposure, population coverage measurement with public wireless networks and reporting of harmful interference.

Study Group 1 and its Working Parties maintain a number of Recommendations (www.itu.int/pub/R-REC) and Reports (www.itu.int/pub/R-REP) that are relating to aforementioned topics. In addition to this, ITU-R SG1 developed and currently maintains three handbooks: The Handbook on National Spectrum Management (www.itu.int/pub/R-HDB-21) that describes the key elements of spectrum management and is intended for the use by both developing and developed countries, the Handbook on Spectrum Monitoring (www.itu.int/pub/R-HDB-23) which is an essential accessory for all spectrum monitoring agencies in the world in developing and developed countries and the Handbook on Computer-aided Techniques for Spectrum Management (CAT) (www.itu.int/pub/R-HDB-01) which contains basic material and numerous models for developing efficient projects that is assisting in implementing automated spectrum management systems.

Wael Sayed is the chairman of Study Group 1 of Radiocommunication Sector in International Telecommunication Union (ITU-R). He serves as acting head for Radio Spectrum Planning Sector in the Egyptian National Telecommunication Regulatory Authority (NTRA). He joined NTRA since 2001 as junior spectrum management engineer. He started participation in the activities of ITU-R since 2003 as a member of the Egyptian delegation to the World Radiocommunication Conference (WRC-03).

Year-by-Year, his involvement in ITU-R activities increased till he was selected by the Egyptian Administration to the deanship of WRC-19 that was held in Sharm El-Sheikh in Egypt in October/November 2019. Also, during ITU Radio Assembly (RA-19) just prior WRC-19, he was the candidate of the Egyptian Administration to the chairmanship of the aforementioned study group.

Wael earned a bachelor degree in telecommunications and electronics engineering form Cairo University in 2000. In addition to that, he had a master of business administration (MBA) in 2018 form Arab Academy for Science, Technology & Maritime Transport (AASTMT). Currently, he is living in Giza-Egypt with his wife and four children.

Research Agenda for Spectrum Management
Dr. David Reed
University of Colorado Boulder

This past month of May I had the pleasure to co-teach with Dale Hatfield a graduate course at the University of Colorado (CU) Boulder on Spectrum Management and Policy. For those of you who don't know Dale, he has been a leader in the U.S. for several decades at the Federal Communications Commission (FCC) and National Telecommunications and Information Administration in developing and implementing innovative, new approaches to spectrum management. The class was composed of master's level electrical engineering and cybersecurity students along with first-year law students, which presented the unique opportunity to address spectrum management problems with an interdisciplinary curriculum incorporating technology, economics, and public policy components.

This teaching experience with Dale, and his encyclopedic knowledge of spectrum regulation, gave me the opportunity to learn more about the significant progress made in spectrum management over the past decade and then to reflect on the current problems facing the research community in developing more efficient and effective use of spectrum to meet societal objectives.

At the risk of over-simplifying, and to keep this discussion brief, here is a short list of current interesting interdisciplinary problems that we addressed during our graduate class that I believe merits ongoing or further research attention:

1. *Spectrum sharing technologies*. The tools available to regulators to facilitate the sharing of spectrum between different services using technical and service rules are increasingly being put to use over the past 5 years. Automated Frequency Coordination systems, Dynamic Spectrum Access, and Shared Access Systems are new approaches to ease coexistence and reduce harmful interference. Research will be needed on how well these systems perform and how new technologies such as artificial intelligence or other data analytics approaches might be employed to improve performance.
2. *Licensed versus Unlicensed Debate*. Spectrum management has moved on from the Command and Control model to predominantly licensed and unlicensed models. Licensed spectrum now provides license holders much greater flexibility in terms of the services that can be offered and the ability to, for example, lease spectrum to others. Unlicensed spectrum allows substantial service flexibility as well subject to limitations on transmit power level. But is this the end game for spectrum management models or will it be possible to continue the evolution to incorporate hybrid licensed/unlicensed models or even new models that push the openness of access for equipment

and service providers alike? Additional research in new types of technical and service rules, auction design and standardization of additional software interfaces could uncover novel spectrum managements models to address additional policy objectives for competition.

3. *Mobile broadband (5G) Driving New Spectrum Allocations.* In somewhat unprecedented fashion, countries throughout the world are racing to deploy more spectrum to support the next generation of mobile broadband technology. While proactive efforts to support 5G spectrum requirements is certainly laudatory, these spectrum allocation decisions could be locking in potential rigidities in the form of legacy laws and service rules unless licensing flexibility is maintained and expanded. An exciting development in broadband availability has been the emergence of low-cost wireless solutions for hard-to-reach areas. How this dynamic mix of local access network options plays out over time, and is linked with government-sponsored universal service programs or national broadband plans, is another area of rich research potential that needs to be better understood by regulators.

4. *Emerging Role of Risk Management.* There now appears to be a role for risk management as part of spectrum management efforts, though it has yet to be fully defined. Based on contributions from Dale and others at Silicon Flatirons at CU Boulder, the FCC has been considering the use of risk-informed interference assessments that take into account receiver performance in order to consider the level of harm resulting from interference. Similarly, given that wireless networks represent critical infrastructure for society, the FCC's Communications Security, Reliability, and Interoperability Council recommended the use of a voluntary, risk management framework for mobile service providers to guide cybersecurity mitigation efforts. Continuing the research to develop and implement these frameworks in these contexts is necessary to further integrate key risk management and risk communication concepts into spectrum regulations.

Obviously, this is not a full list of pressing research topics on spectrum policy; there are many others that can be added to this list. The important point here is that the increasing importance of mobile communications to meet societal connectivity objectives continues to elevate the importance and urgency of ongoing research into new and improved spectrum management models and tools.

One of the goals of GTPRN is to provide a networking forum for researchers to discuss, develop and coordinate research agendas of topics of current significance to the global technology policy community. While it is not clear how best to proceed, GTPRN may be a useful platform to start or reignite this conversation on an international basis. Perhaps a meet-up at a future TPRC, ITS or Silicon Flatirons conference?

Dr. David Reed is currently a Scholar in Residence. Prior to joining CU, Dr. Reed was the Chief Strategy Officer at Cable Television Laboratories where he led large R&D projects covering a wide range of technologies relevant to the cable industry such as application platforms, business services, voice-over-IP, and broadband delivery systems. Dr. Reed also has been a Telecommunications Policy Analyst in the Office of Plans and Policy at the Federal Communications Commission where he worked on cable-telco competition, personal communications services (PCS), and spectrum auction policies. Dr. Reed has authored a book on residential fiber optic networks, and is a widely published author in telecommunications journals, books, and magazines. He has been an author of interdisciplinary analyses that played key roles in defining U.S. policy debates on PCS spectrum allocation and local access competition.

Dr. Reed holds a BS in Electrical Engineering from Colorado State University, an MS in Electrical and Computer Engineering from Carnegie Mellon University and PhD in Engineering and Public Policy from Carnegie Mellon University.

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o Microsoft Funded PhD: Using AI to develop joint attention in blind children Primary Supervisor: Dr Oussama Metatla, The Bristol Interaction Group (BIG), Department of Computer Science, University of Bristol. Microsoft Research Supervisor: Dr Cecily Morrison, Microsoft Research Cambridge (MSRC), Read more For further details or to discuss this contact Dr Oussama Metatla including a full CV and any relevant details.