Sistemas de Comunicaciones

Master en Ingeniería de Telecomunicación

Presentation

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Dep. Teoría de la Señal y Comunicaciones

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Universidad de Sevilla

First Semester (C1) 2023/24

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General Information

General Information

- Asignatura: Sistemas de comunicaciones
- Duración: 5 créditos, 40 horas presenciales + 85 horas no presenciales.
- Aula: 309A
- Horario: Lunes y Martes de 9:00 a 10:30 h
- Profesorado:

Profesor	email	Tutorías	Localización
Juan José Murillo Fuentes	murillo@us.es	Mx, 8:30-14:30	Despacho 06 Planta E2, Esquina NE

Con la colaboración de Pablo Aguilera Bonet, paguilera@us.es

- Recursos:

Recurso	Descripción
`http://ev.us.es`	Enseñanza Virtual
`http://personal.us.es/murillo`	Página personal
`https://departamento.us.es/dtsc/`	Página departamental

Units

- Background: Propagation and Link Budget

1. Digital Communications
   - 1.1. Parts of communication system
   - 1.2. Espectrum
   - 1.3. Examples of systems
2. Modulations in AWGN channel
   - 2.1. Modulations
   - 2.2. Detection in AWGN channel
   - 2.3. Multidimensional AWGN channel
3. Modulations in selective channel
   - 3.1. Low-pass equivalent model
   - 3.2. OFDM
   - 3.3. DSSS

Evaluation Units 0-3

4. Fading Channels
   - 4.1. LTI models
   - 4.2. LTV models: Doppler
   - 4.3. Channel parameters
   - 4.4. Stochastic channels: WSSUS
   - 4.5. Non linear and non-Gaussian
   - 4.6. Notes on MIMO
5. Diversity
   - 5.1. BER in Rayleigh channel
   - 5.2. Time diversity
   - 5.3. Spatial diversity
6. Example of system: WiFi-6

Evaluation Units 4-6

Main References

1. Fundamentals of Wireless Communication. David Tse and Pramod Viswanath. Cambridge University Press, 2005
2. Modelling the Wireless Propagation Channel: A simulation approach with Matlab Fernando Pérez Fontán, Perfecto Mariño Espiñeira. Wiley 2008

Other references

- MIMO Wireless Communications. E. Biglieri *et al.*2010 Cambridge University Press
- Wireless Sensor Networks. Principles, Design and Applications. S-H Yang Springer 2014
- Problemas de Radiocomunicación. J.J. Murillo Fuentes, Col. Mon. ETSI. Univ. Sevilla, 2014
- CDMA Principles of Spread Spectrum Communication. Andrew J. Viterbi. Addison-Wesley. 1995
- MIMO-OFDM Wireless Communications with MATLAB. Y.S. Cho, J. Kim, W.Y. Yang. N2010
- WCDMA for UMTS - HSPA evolution and LTE. H. Holma and A. Toskala John Wiley and Sons, 2007
- LTE and the Evolution to 4G Wireless: Design and Measurement Challenges. M. Rumney, 2nd Ed. Agilent Technologies. John Wiley & Sons. 2013

Teaching Methodology

- Se indicará la bibliografía utilizada para cada epígrafe.
- Y se aporta material de apoyo. Este material se desarrollará a lo largo del curso a modo de clase en el aula.
- Se incluyen test para ir resolviendo durante las clases.
- Se apoyará la teoría con ejercicios y problemas, por un lado, y con las simulaciones o prácticas por otro.
- Se propondrán también Tareas a realizar, en la forma de problemas y simulaciones.
- Las simulaciones se harán utilizando software matlab o equivalente. Se evaluarán con preguntas en los exámenes.
- Se realizarán dos controles durante el curso. Cada uno de ellos supondrá aproximadamente la mitad de la nota final.
  - Es necesario aprobar cada uno de ellos con una nota mínima. Si no se supera alguno de ellos se podrá aprobar en el examen final.
  - No se guardarán parciales para la segunda y tercera convocatoria.
- En tutorías podemos resolver dudas, comentar aspectos de las asignaturas o proponer mejoras ante malos rendimientos académicos.

Motivation

Motivation

- Traffic
  - The demand of traffic has grown exponentially
  - The number of connected devices grows exponentially (M2M, IoT)
  - Spectrum is scarce
  - How to best exploit it?
  - How much can we exploit it? (C. Shannon = capacity)
- But.... What is what we must exploit? How is the transmission channel?
  - Does it change along frequency?And along time?
  - What does diversity mean?
  - What is the impact of the technology on wireless systems? (e.g. cellular)

Motivation

Samsung Demos Multi-Gbps Speeds Using 60 GHz Wi-Fi

By Ian Chant
Posted 22 Oct 2014 | 20:12 GMT

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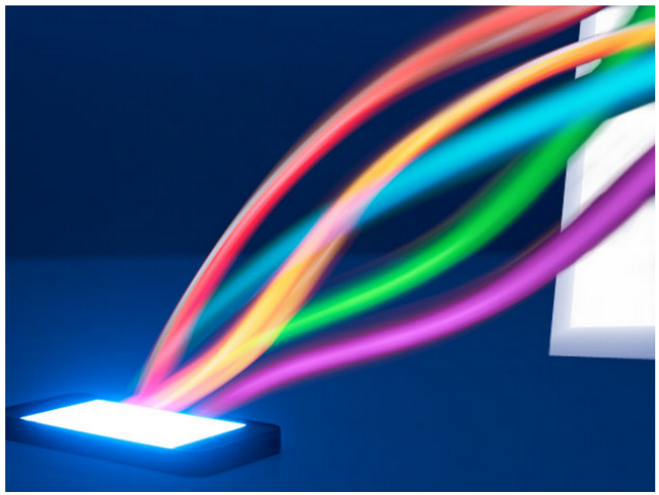

Image: Getty Images

Figure: Spectrum at 60 GHz (millimetre-wave)

Swedish Researchers Report Record Wireless Data Transmission Rate

By Alexander Hellemans
Posted 6 Nov 2014 | 18:00 GMT

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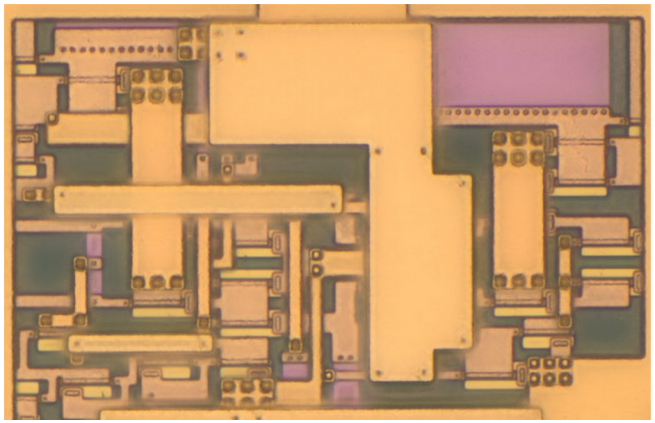
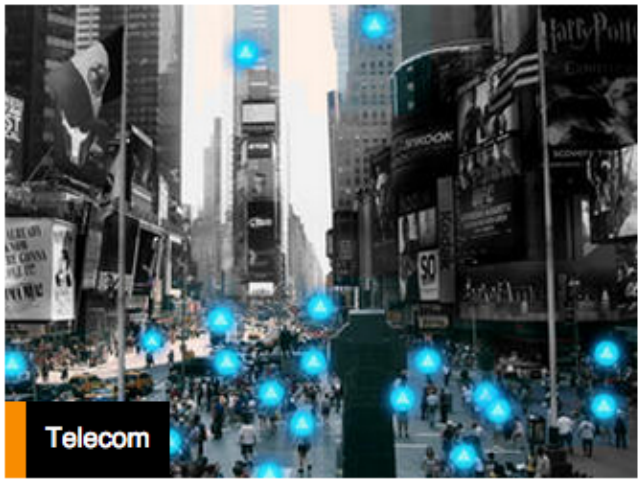


Figure: Increasing throughput

Motivation

Figure: Massive MIMO



5G Service On Your 4G Phone?

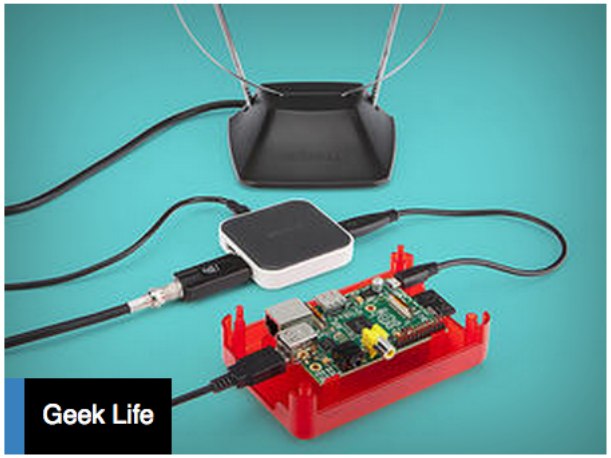
Start-up Artemis Networks aims to leapfrog 4G LTE with new "pCell" technology.

19 Feb 2014

Figure: hi-speed: pCell

Motivation

SDR, Software Defined Radio



A $40 Software-Defined Radio

A repurposed TV tuner can reveal a wide swath of spectrum

25 Jun 2013

Figure: Cheap SDR

Photo: Darpa

Flying Bits: The 465 square-meter, 400-node ORBIT radio grid facility at Rutgers University, in New Jersey, hosted DARPA Spectrum Challenge software defined radio algorithms in head-to-head competitions.

Figure: SDR for testing

Motivation

Understanding Wireless

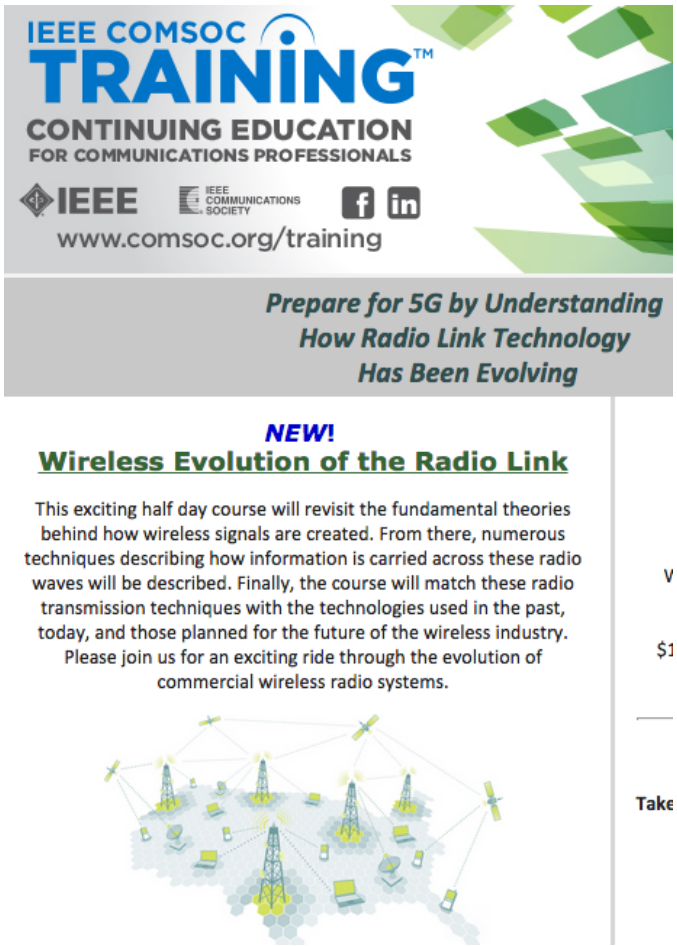


Figure: Training

Welcome to the February issue of the IEEE ComSoc Technology News (IEEECTN) - "Toward the Open Basestation," released by the new Editor-in-Chief Alan Gatherer. Alan is a Chief Technology Officer at Huawei, Baseband on System Chip.

Traditionally the Basestation in a cellular network that covers approximately layer 1 through layer 3 of the network functionality and is seen as a closed box into which bits go in and waveforms come out, and vice versa.

In this issue, IEEE CTN explores the dynamic network in reality in comparison to traditional network, to discover rules and trends that can be taken advantage of.

Basestation is a new area of research for wireless cellular that sits at the intersection of scheduling, software defined networking, and wireless modem design. Trends, short term events, and even user movement can affect Basestation resource and user patterns.

IEEE CTN challenges researchers to take it further by thinking about Basestation being designed as a collection of services that are utilized in a statistical manner to achieve the desired results. Flexibility and user centric networking is likely to become important in 5G and will require a very flexible Basestation.

Figure: Open Base Station

Motivation

- 5G to commercial

Figure: 5G

See much more at https://spectrum.ieee.org/telecom/wireless

Motivation

- 5G Nb-IoT

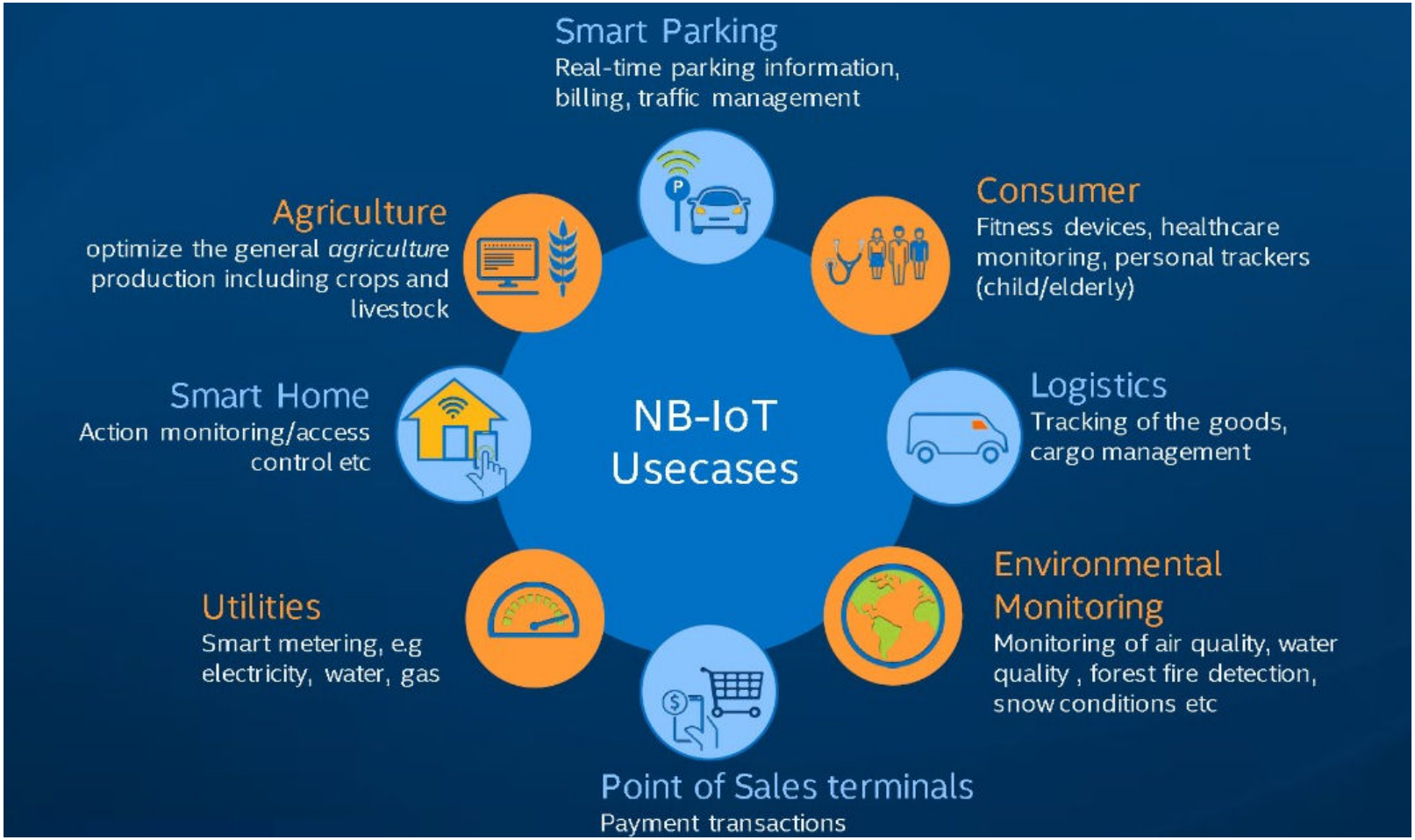


Figure: From

`https://telecoms.com/opinion/nb-iot-setting-the-pace-in-the-race-to-5g/`

Motivation: MAIN OBJECTIVE

In the end, this is all about *ESPECTRAL EFFICIENCY* and *LATENCY*

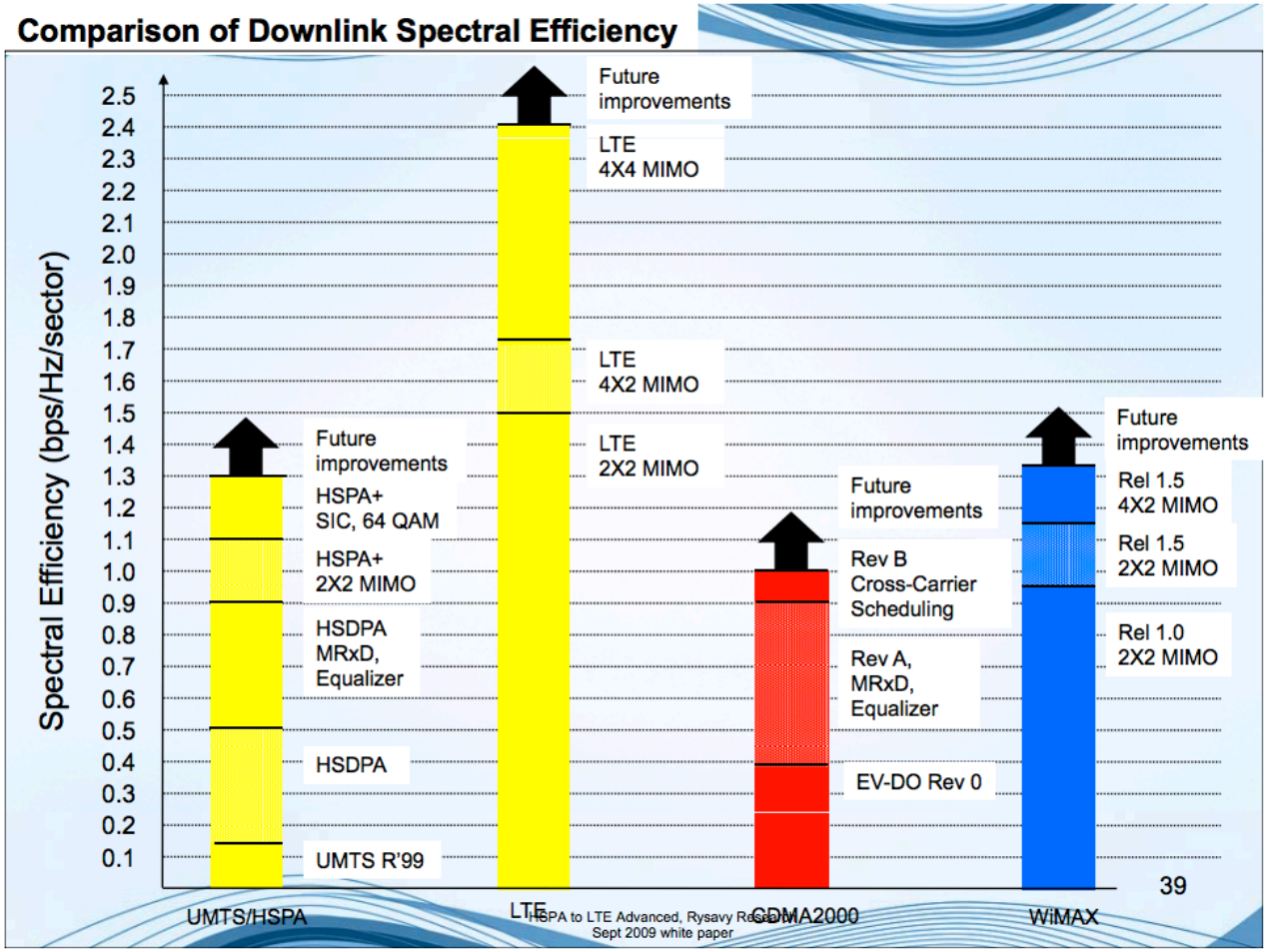


Figure: Espectral Efficiency

Trends 2020

1. THz Spectrum Heats Up Talk of 6G

Last year we discussed the promise of huge swaths of bandwidth in the frequency frontier that *ranges between 100 GHz and 1 THz*, along with a blend of new possibilities waiting up there, not only in terms of bit rates, but of high-resolution positioning and imaging as well. Having published a post devoted to this issue just weeks ago, we continue to expect that this topic will become one of the big ones of 2020 and we moved it up to pole position in the list. But we recognize that this will be a process and that it will take time (and research!). The first step in this process is, in fact, the *deployment of mmWave 5G components*, and the ongoing trials are providing an unprecedented wealth of data on how signals propagate at these frequencies, especially outdoors. In many cases, the non-line-of-sight coverage is proving to be more robust than anticipated thanks to reflections, which is welcome news, not only for 5G itself, but further for the prospects of what lies beyond. Let's see where we are a year from now...

`https://www.comsoc.org/publications/ctn/nine-communications-technology-trends-2020`.

2 . AI Reaches the Boonies with Federated Learning

Our prediction last year was that AI would start to roll down the hype curve, but we were wrong. Last year was the year of *edge computing* for everything and the hot topic of 2019, Machine Learning, was not immune to this influence. Much good work was done towards an understanding of how machine learning could be distributed to reduce the latency of inference as well as reducing the bandwidth of data moving back to the cloud for training. In addition, some folks have proposed that *federated learning* can occur with only encrypted data moving to the cloud so that we can learn even when we don't know what it is we are learning! So with 2019 being the year of training at the edge of the network, we expect that 2020 will see federated learning move solidly into the handset.

3. Meta-materials, Meta-surfaces, Meta-resonators, Meta-anything

A theme that has quietly but manifestly moved into a rather central position in the discussions on the evolution of wireless communications is that of meta-materials. Broadly speaking, *a metamaterial is an artificially structured material that allows controlling and influencing the flow of electromagnetic waves (or possibly of other types of waves)*. Metamaterials are typically arranged in repeating patterns, at scales smaller than the wavelength of the waves they seek to mold, and their properties emanate precisely from these patterns. Efforts are underway to design antennas based on meta-materials, say for massive MIMO, that could incorporate some of the signal processing functionalities directly on the antenna structures, and antennas based on meta-resonators that could be more compact and broadband than regular antennas. An even more intriguing development is that of *intelligent reflecting surfaces*, which could be deployed in strategic locations and reflect signals on a dynamically adjustable fashion. Taking the idea to the limit, think off a world where multipath propagation was a controllable phenomenon rather than an imposition from nature. It's too soon to tell whether these meta-surfaces can be a transformational development, or merely an anecdotal re-incarnation of good old relays. Only time and research will tell.

4. The Cellphone is Dead. All Hail IoT!

This was our prediction last year and we are calling it. OK, maybe the cell phone isn't exactly dead but the Financial Times ran an article in October with the headline "Apple's wearables and services drive revenue as iPhone sags", so if not dead it is showing its old age. Certainly 2019 was the year of IoT more than it was the foldable screen (Though that was also pretty cool) and we expect that IoT will be a hot topic for 2020, especially in the areas of *Factory 4.0, V2X and enterprise*. In 2019 the 3GPP standards process was all over trying to define use cases for these new, and potentially massive, applications. Note that in these cases the IoT isn't the slave to a phone but an ecosystem all by itself with some very unique requirements that are now driving *URLLC*. Expect to hear a lot more as this starts to roll out in big manufacturers like Mercedes, Bosch and Foxconn.

Note: Ultra Reliable Low Latency Communications (URLLC)

5. Cellular is Dead. All Hail IT!

OK, we just said that to attract your attention. But 2019 was the year of IT insurgency into traditional cellular operator arenas, and we would like to point out that we did call 2019 the year of IT convergence. We expect this to continue. In particular, we expect that Edge compute will continue to be a hot topic and that the impact of ORAN's attempts to commoditize the RAN will become clearer in 2020. After all of the hype of 2019 we are tempted to predict that 2020 will be a year of adjusting for reality in the IT convergence at the network edge.
https://www.o-ran.org/

6. The Year the Telecom World Cracked

Are we touching a third rail here? 2019 was the year that the Global ecosystem that telecoms had sat on top of for decades started to crack and governments got into the telecom regulation business in a way that we haven't see in a long time, if ever. You know what we are talking about. This process will continue into 2020 and, needless to say, there will be winners and losers. Your humble editorial board will stick to the technology side of this and stay away from the politics and business side. But it is hard to imagine this is not a hot topic in 2020 for technology.

7. Come Fly with Me, and My Network

Driven by an emerging use of flying platforms such as *unmanned aerial vehicles (UAVs), drones and unmanned balloons* in future network applications and the challenges that the 6G networks exhibit, last year we noticed loads of research and development activities that demonstrate the evolution of the flying platforms as a novel architectural enabler for radio access network (RAN) and their integration with the future cellular access and backhaul/fronthaul networks. It seems that these platforms could be used as potential way to offer high data rate, high reliability and ultra-low latency access and backhaul/fronthaul to future wireless networks. Such large scale and flexibly deployable platforms and frameworks may guarantee the global information and communication requirements in future smart and resilient cities and solve the ubiquitous connectivity problems in many challenging network environments, e.g., coverage or capacity enhancements for remote or sparsely populated areas, social gathering and disaster affected scenarios, etc and responding to United Nation's sustainable development goals and societal challenges.

8. Massive MIMO Implementation Becomes a Career Plan

Yet again typing "massive MIMO implementation" into IEEE explore once again reveals that the rise in paper density has pretty much rooflined since 2017 at around 100 papers a year. We promise not to mention it again.

9. Everyone is Slicing and Virtualizing

Globecom in December was awash with papers on RAN slicing and we expect this trend will continue to ramp for a while because the availability of open source frameworks and data is now allowing universities to finally apply some of that theory in a meaningful way. Some folk believe that this will be a trend that will fundamentally alter the landscape of the telecoms industry. Some of us older folk remember CloudRAN and NFV and get a similar feeling about this time around. But either way we will call 2020 as the year that everyone got comfortable with slicing anything that moves in the telecom network.

Trends for 2021

CHECK FOR 2021 YEAR TRENDS!!

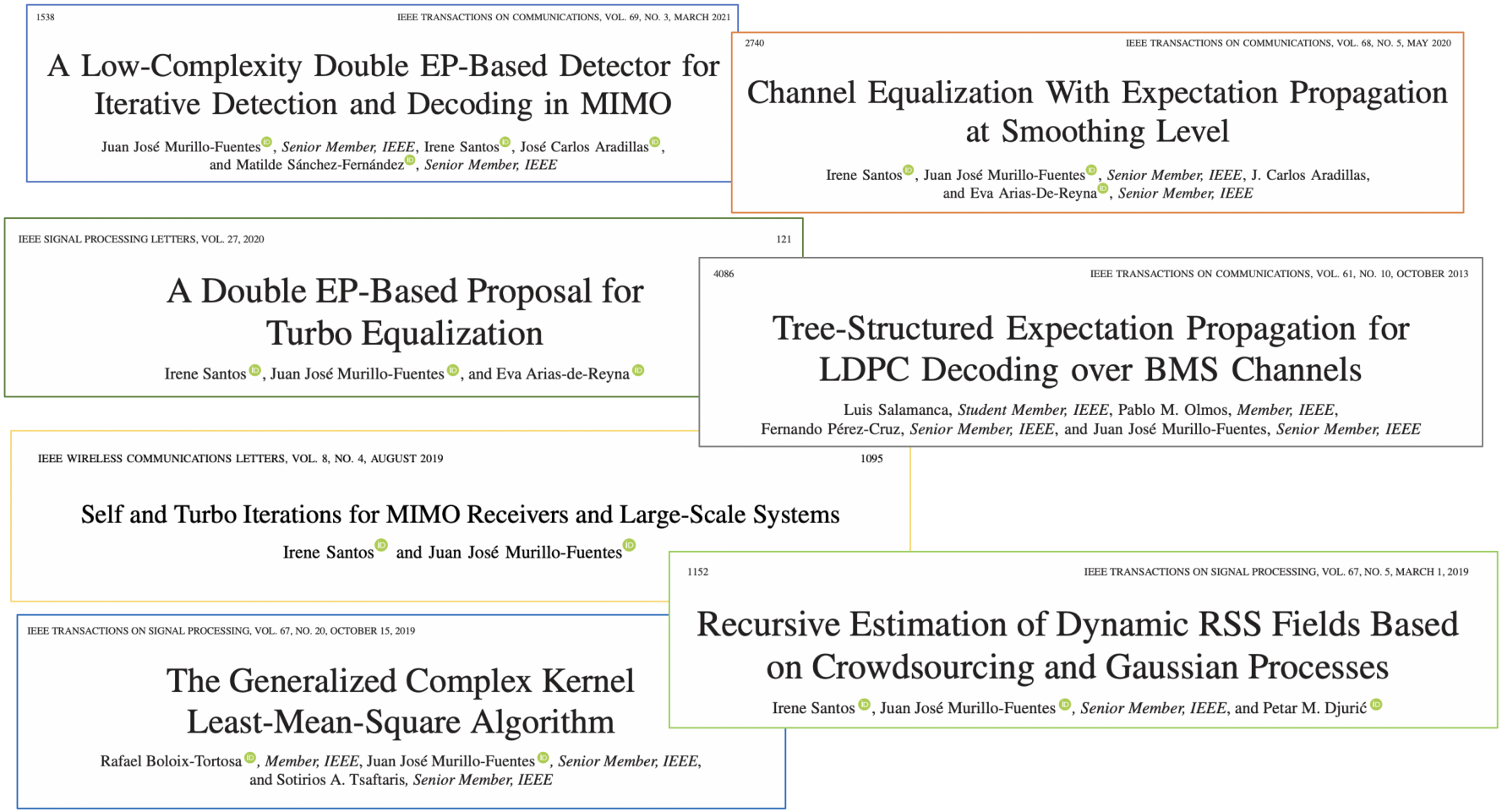
https://www.comsoc.org/publications/ctn/seven-communications-technology-trends-2021

Teacher

About Me

- Teaching digital and wireless communications since 2001 in
  - Laboratorio de Comunicaciones Digitales. Ing. de Telecomunicación. Universidad Carlos III de Madrid.
  - Radiación y Radiocomunicación. Ing. de Telecomunicación. Universidad de Sevilla.
  - Comunicaciones Móviles. Ing. de Telecomunicación. Universidad de Sevilla
  - Sistemas de Radiocomunicación. Grado en Ing. de Tecnologías de Telecomunicación.
  - Sistemas de Comunicaciones Inalámbricas y por Cable. Máster Universitario en Ing. de Telecomunicación.
- Author of (see `https://personal.us.es/murillo/docencia/`)
  - Juan José Murillo-Fuentes, "Fundamentos de radiación y radiocomunicación". Escuela Técnica Superior de Ingenieros, 2007.
  - Juan José Murillo-Fuentes, "Problemas de Radiación y Radiocomunicación". Colección Escuela Técnica Superior de Ingenieros, Editorial Universidad de Sevilla 2017.
- Teacher at the
  - Máster Vodafone, Universidad de Sevilla.
  - Máster RPAS, Universidad de Huelva.
  - Courses for Navantia and Motorola.
- Research on several topics , mostly applying machine learning to:
  - Channel Equalization
  - Chanel decoding
  - MIMO detection, including Massive MIMO
  - Complex-valued formulations
  - Crowdsourcing for RSSI estimation

Some works on the topic



1538 IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 69, NO. 3, MARCH 2021

A Low-Complexity Double EP-Based Detector for Iterative Detection and Decoding in MIMO

Juan José Murillo-Fuentes, *Senior Member, IEEE*, Irene Santos, José Carlos Aradillas, and Matilde Sánchez-Fernández, *Senior Member, IEEE*

2740 IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 68, NO. 5, MAY 2020

Channel Equalization With Expectation Propagation at Smoothing Level

Irene Santos, Juan José Murillo-Fuentes, *Senior Member, IEEE*, J. Carlos Aradillas, and Eva Arias-De-Reyna, *Senior Member, IEEE*

IEEE SIGNAL PROCESSING LETTERS, VOL. 27, 2020 121

A Double EP-Based Proposal for Turbo Equalization

Irene Santos, Juan José Murillo-Fuentes, and Eva Arias-de-Reyna

4086 IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 61, NO. 10, OCTOBER 2013

Tree-Structured Expectation Propagation for LDPC Decoding over BMS Channels

Luis Salamanca, *Student Member, IEEE*, Pablo M. Olmos, *Member, IEEE*, Fernando Pérez-Cruz, *Senior Member, IEEE*, and Juan José Murillo-Fuentes, *Senior Member, IEEE*

IEEE WIRELESS COMMUNICATIONS LETTERS, VOL. 8, NO. 4, AUGUST 2019 1095

Self and Turbo Iterations for MIMO Receivers and Large-Scale Systems

Irene Santos and Juan José Murillo-Fuentes

1152 IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 67, NO. 5, MARCH 1, 2019

Recursive Estimation of Dynamic RSS Fields Based on Crowdsourcing and Gaussian Processes

Irene Santos, Juan José Murillo-Fuentes, *Senior Member, IEEE*, and Petar M. Djurić

IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 67, NO. 20, OCTOBER 15, 2019

The Generalized Complex Kernel Least-Mean-Square Algorithm

Rafael Boloix-Tortosa, *Member, IEEE*, Juan José Murillo-Fuentes, *Senior Member, IEEE*, and Sotirios A. Tsaftaris, *Senior Member, IEEE*

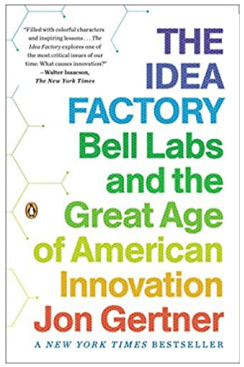
For further information:

- https://personal.us.es/murillo/research-lines/
- https://ieeexplore.ieee.org/author/38272011400
- https://investigacion.us.es/sisius/sis_showpub.php?idpers=7312

Historical notes

Historical Notes

- A historical review is out of the scope of the corse
- However, I quite encourage the student to review some books and urls on this topic:
  - If I had to recommend one book: "The Idea Factory. Bell Labs ..."



  - "De las señales de humo a la sociedad del conocimiento. 150 años de l telecomunicaciones en España". Foro Histórico de las telecomunicaciones. Ed. COIT. 2006.
  - Ángel Faus Belau "La radio en España (1896-1977)'. Una historia documental" Ed. Taurus Santillana. 2007.
  - `https://forohistorico.coit.es`
  - `https://en.wikipedia.org/wiki/History_of_telecommunication`
  - `https://spectrum.ieee.org/topic/tech-history/`
- Some names: J.C. Maxwell, Marconi, C. Shannon, ...

Bell Labs

Figure: Bell Laboratories in 1925, New York

- Now Nokia Bell Labs, formely named Bell Labs Innovations
  - Bell Labs Innovations, 1996-2007
  - AT&T Bell Laboratories, 1984-1996
  - *Bell Telephone Laboratories, 1925-1984*
- Created (1925) under the ownership
- Researchers working at Bell Labs are credited with the development of
  - radio astronomy (1931), cosmic microwave background (big bang) (1965),
  - the transistor (1947 BJT), then the MOSFET (1958),
  - first telephone (TAT-1, 1955) and fiber-optic (TAT-8, 1988) transatlantic cables,
  - the laser (1958) and the photovoltaic cell (1940),
  - Telstar satellite (1962), first satellite relayed TV,
  - OFDM (1968),
  - the charge-coupled device (CCD) (1969),
  - TDMA and CDMA digital cellular phone (1980),
  - *information theory*,
  - the Unix OS, and programming lenguages C/C++,...
- *Nine Nobel Prizes* have been awarded for work completed at Bell Laboratories.
  - Spain has eight Nobel laureates (6 Literature, 2 Medicine)
- Researchers: Nyquist, Johnson, Bode, Shannon, Hartley, Hamming, Penzias and Wilson, Ritchie, Tukey, Karnaugh...