Computational Holographic Radio and Enabling Technologies for 6G

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CONTENTS

- **Introduction**
- **Concept of Computational Holographic Radio - HoloRadio**
- **Key Enabling Technologies of HoloRadio**
- **Summary, Challenges and Open Problems**

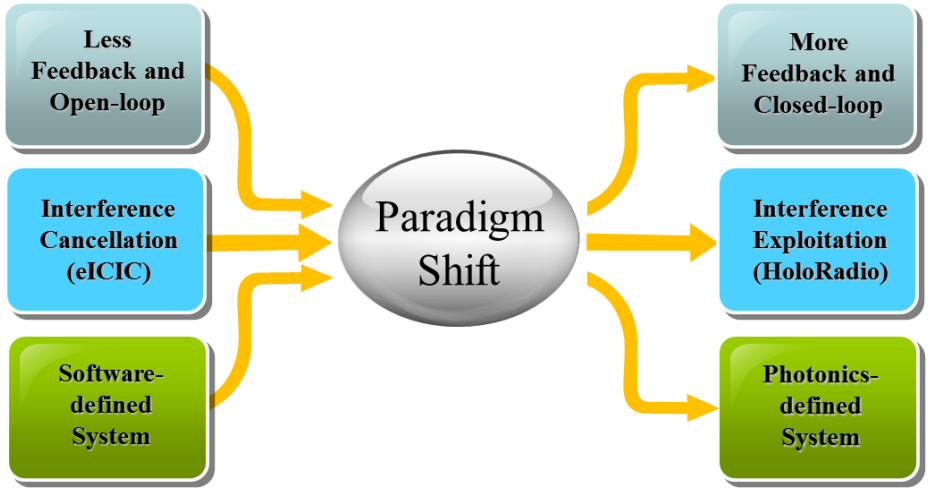
Introduction

- 5G is still faced with unprecedented challenges in many aspects, such as open fronthaul, converged system architecture of computing and communication, as well as new breakthrough technologies.
- From 4G, operators have attempted to build an open BBU-RRU interface, but from CPRI to eCPRI it seems to be far from this goal.(***Caroline Gabriel et al, 2018***)
- 5G continues the technological path of the previous mobile communication and is still the extension of 4G, resulting in beginning to touch the ceiling of performances.

Introduction

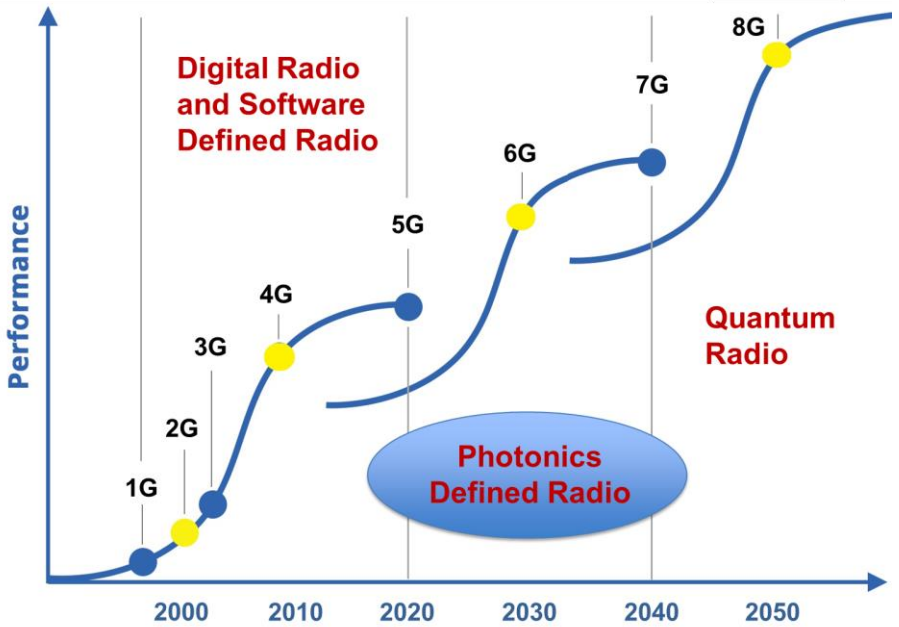
6G needs new theories and paradigms, as well as innovative and breakthrough technologies:

- Resource management transforms from open-loop to full-closed-loop;
- Interference cancellation transforms into interference exploitation;
- From software defined system to photonics defined system.



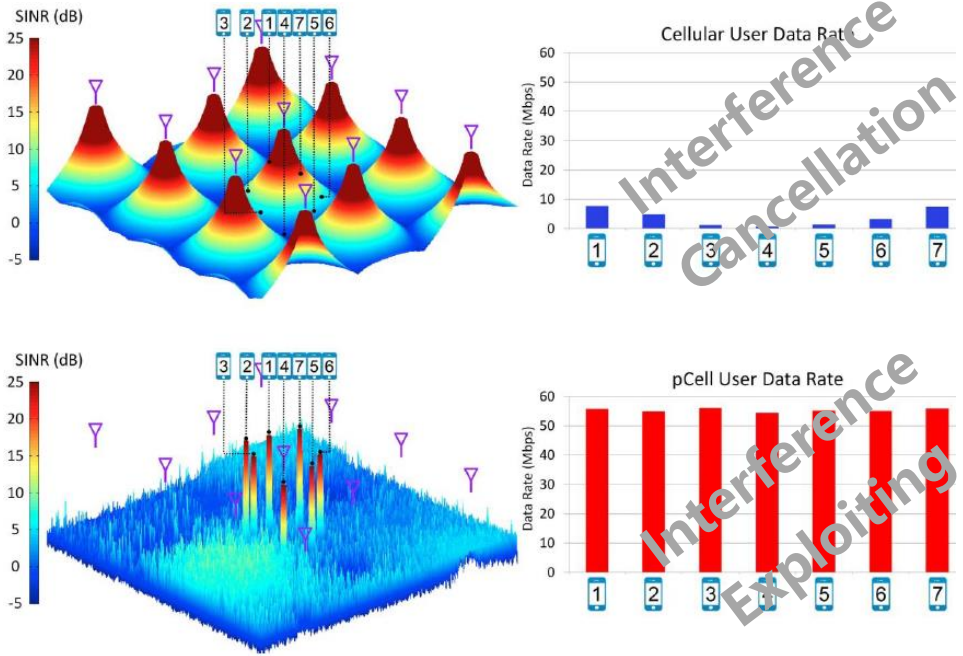
Introduction

As a new paradigm and disruptive technology, Photonics Defined Radio, converging integrated coherent optics, IMWP and photonic ADC/DAC/DSP, was proposed and expected to dominate the designs of future radio and sensing systems. Referred to digital radio for 2G and software defined radio for 4G, **photonics defined radio** (PDR) will be the fundamental enabling and supportive technology of 6G. (***Source: Zong Baiqing, et al, 2018***)



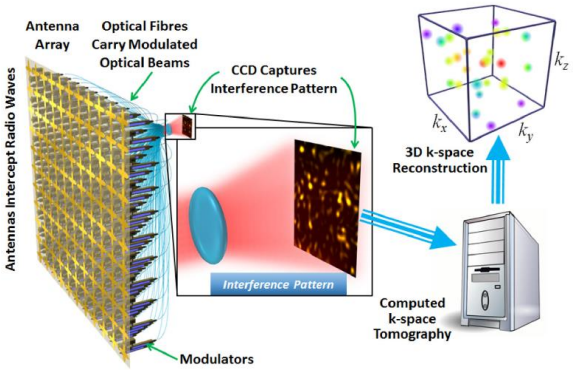
Introduction

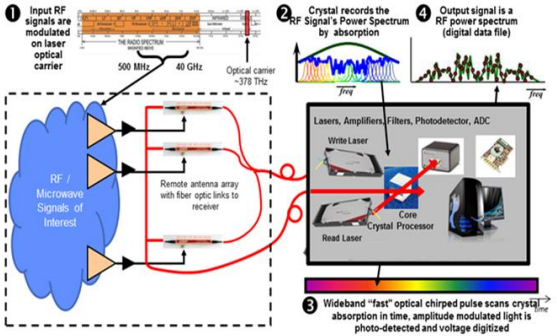
Interference exploitation has achieved the gains by exploiting interference in wireless networks through large scale cooperation between distributed transceivers, and by enabling high spatial multiplexing gain via multiuser transmissions. (***Antonio Forenza et al, 2015***)



Introduction

- RF tomography (***Source:* JANUSZ MURAKOWSKI, *et al, 2017***) and spatial spectral holography (***Source:* Zeb W. Barber, *et al, 2017***) show potentials in interference exploitation by full-space spectral coordination.
- However, these technologies seem to focus on uplink signal processing such as imaging and RF mapping.





Introduction

- In this presentation, systematic concepts of spatial wave field synthesis and computational holographic radio are proposed. Computational holographic radio converges **spatial spectral holography** for uplink and **spatial wave field synthesis** for downlink, may not only promote the convergence of communication and imaging, enhance spatial multiplexing gain, but also probably become a candidate of labelled technologies of 6G.

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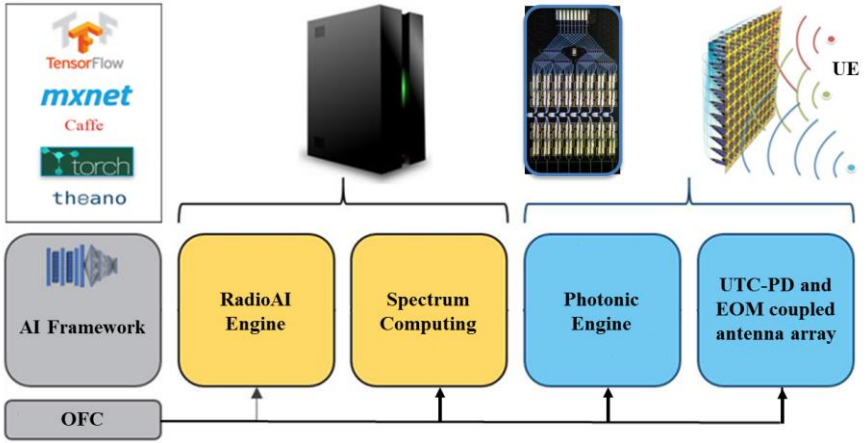
Computational holographic radio (HoloRadio)

- Computational holographic radio is built on photonics defined radio (PDR) platform.
- The photonic front-end (PFE) or photonic antenna array (PAA) performs the transmission, reception and conversion of optical or RF signals.
- The photonic engine (PE) realizes signal generation and processing in the optical domain, such as optical FFT.
- The functions of spectrum computing (SC) are that they act as signal simulator, channel simulator, wave field synthesis module and deep cognitive radio engine.

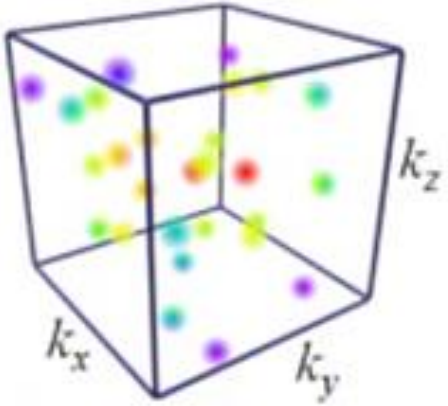


Computational holographic radio (HoloRadio)

- In uplink, the function of spatial-spectral holography converts the RF signals transmitted by UEs from each antenna element to the optical frequency through an electro-optical modulator (EOM) coupled antenna array.
- Then the optical signal outputs are aggregated into an optical FFT processor. Finally, the optical signals processed by holographic interference are converted by a two-dimensional addressable photodetector to electrical signals. The photonic engine (PE) realizes signal generation and processing in the optical domain.
- At this time, signals from different UEs have been accurately separated, and the whole processing is similar to a real-time three-dimensional "light" field imaging in RF domain.

Computational holographic radio (HoloRadio)

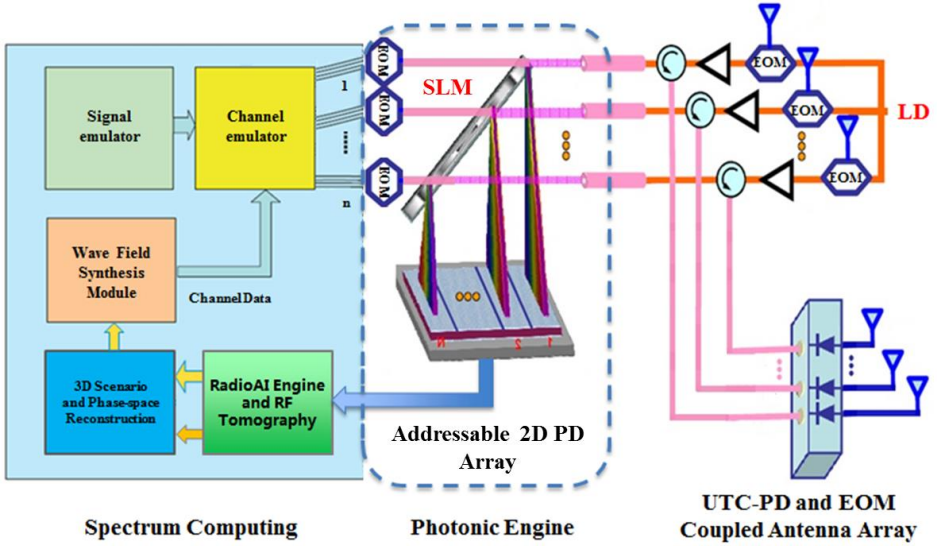
- Moreover, a limited RF aperture has been transformed into a near infinite optical aperture, which enables RF signals to be pre-coded and multiplexed in a nearly continuous spatial spectrum, thus achieving extremely high data throughput and multiplexing gain.
- At the same time, a 3D constellation of UEs in RF phase-frequency space can be obtained through spatial spectral holography, providing precise feedback for spatial wave field synthesis in the downlink.



3D constellation of UEs in RF phase-frequency space

Computational holographic radio (HoloRadio)

- In downlink, spatial wave field synthesis accurately controls multiple modules, including signal simulator, channel simulator and wave field synthesis module, based on the 3D constellation of phase-frequency space of UEs built up by the spatial spectrum holography.
- The complex and accurate distribution of electromagnetic field in target space is realized by a series of PD coupled antenna arrays controlled by signal simulator, channel simulator and wave field synthesis module to transmit specific RF signals.
- The entire process is similar to a real-time holographic "light" field projection in RF domain.



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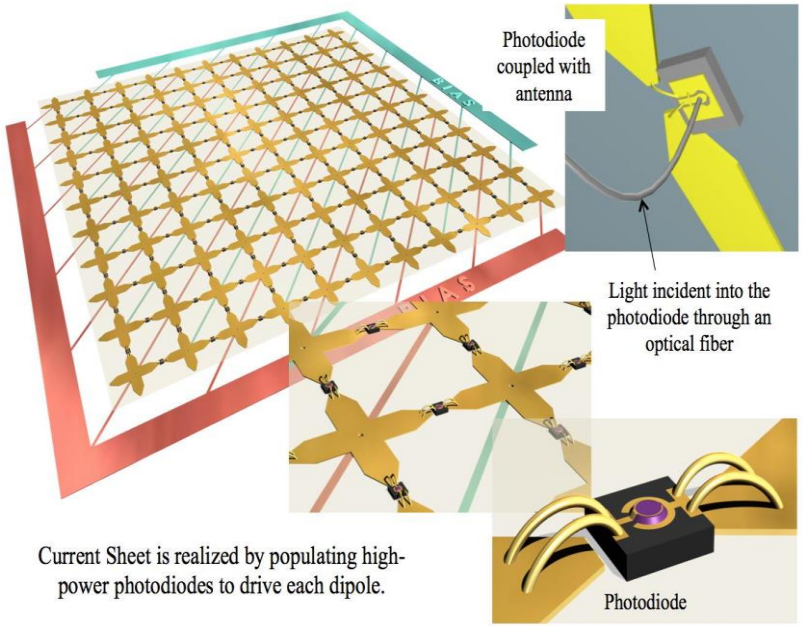
Key enabling technologies of computational holographic radio

- In order to achieve the above spatial spectral holography and spatial wave field synthesis, the antenna array has a flexible transmission aperture, that is, the transmission aperture that can radiate the distribution of holographic RF signals.
- To cope with this challenge, a photodiode coupled antenna array is required, in which the current sources of the excited coupled dipole elements are high power uni-traveling carrier photodiodes (UTC-PD). (***Matthew R. Konkol et al, 2017***)



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Summary, Challenges and Open Problems

- 6G needs new theories and paradigms, as well as innovative breakthrough technologies.
- As a new paradigm and disruptive technology, Photonics Defined Radio will be the fundamental enabling and supportive technology of 6G.
- 6G regards interference as a useful resource for developing energy efficient and secure communication systems.
- The most potential and highest level of interference exploiting is the technology of computational holographic radio.
- Holographic radio realizes the precise control of the entire space and the full closed loop of the electromagnetic field through spatial spectral holography and spatial wave field synthesis, thus greatly improving the spectrum efficiency and network capacity, and even realizing the integration of imaging and wireless communication.

Summary, Challenges and Open Problems

- Lack of models of computational holographic radio.
- challenges of hardware design and physical layer implementations.
- Spectral efficiency, network capacity and performance analysis of holographic radio.
- RF hologram acquisition, recording and processing methods and techniques.
- Large scale spatial wave field synthesis, modulation and manipulation.
- Rapid reconstruction of phase-frequency space of distributed UEs.
- Digital optical signal processing and high performance optical computing technologies.

Thank you

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