Introduction à la Radio Logicielle

Software Defined Radio

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Objectifs du TP CELL

- Présenter la radio logicielle - *Software Defined Radio (SDR)* - entre théorie et pratique.
- Applications SDR dans des domaines de recherche récents: SDN, NFV, Cloud-RAN…
- TP sur GNURadio: Transmission et réception d'un signal.

Plan

1. Qu'est-ce que la radio logicielle?
2. Contextes en Com-ss-Fil (Wireless Nx).
   Exemple du Cloud-RAN
3. GNURadio: outil de modélisation SDR par blocs
4. TP sur GNURadio

Contexte

- Avec la croissance exponentielle des moyens de communications (GSM, VoIP, vidéo, bluetooth, messagerie de diffusion, de commandement et de contrôle…), il est devenu nécessaire de modifier les dispositifs de communication radio facilement et de manière rentable.

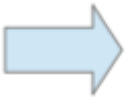
- La technologie de radio logicielle (SDR) apporte la flexibilité, la rentabilité et la puissance pour conduire les communications vers l'avant, avec des bénéfices importants réalisés par les fournisseurs de services et les développeurs de produits jusqu'aux utilisateurs finaux.

Définition de SDR:

La radio définie par logiciel – Software Defined Radio (SDR) –,

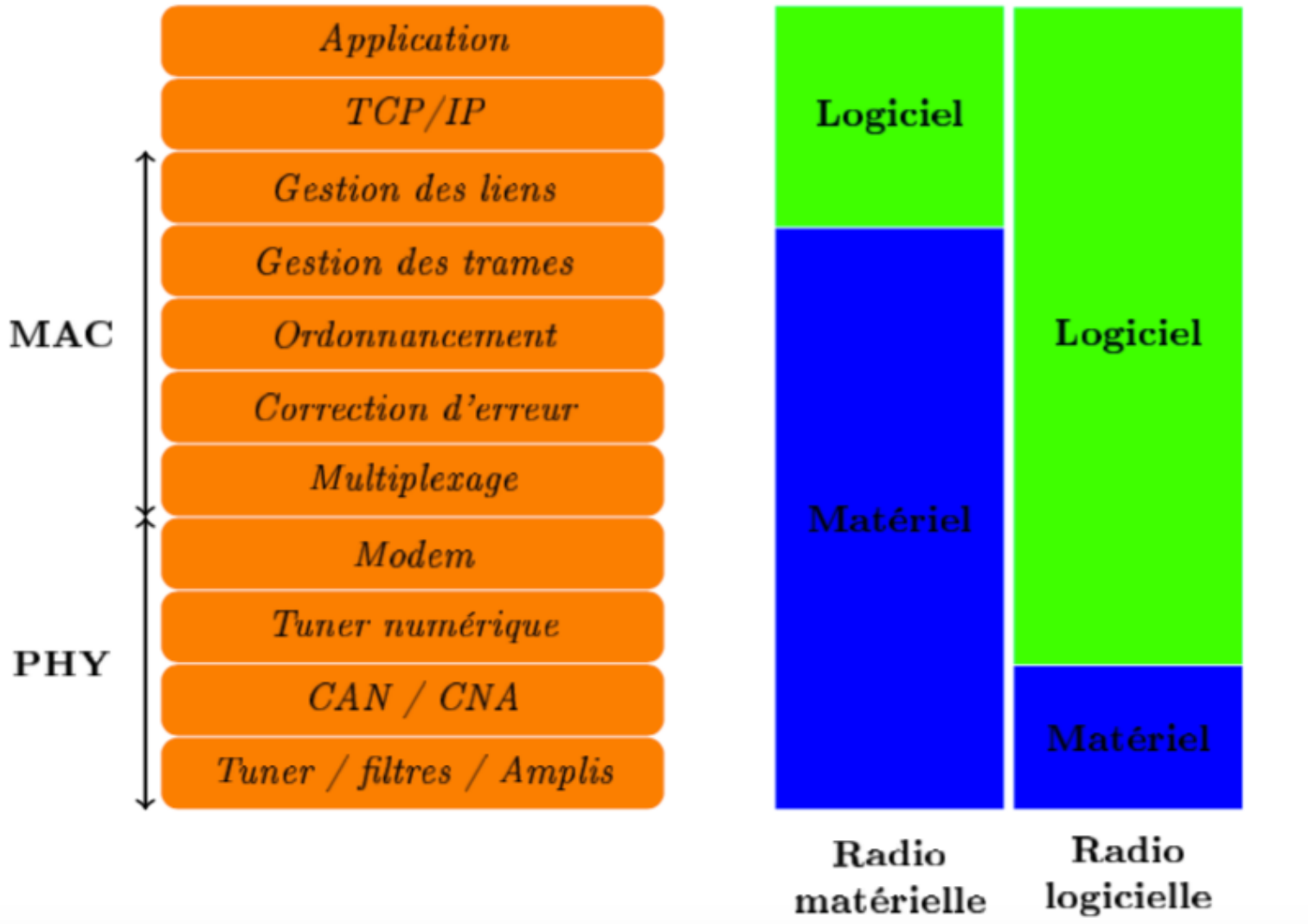
est une nouvelle approche au traitement du signal et de données radiofréquences, déportant un grand nombre de traitements et de fonctions de calculs sur un logiciel, au lieu de dépendre du matériel.

SDR



Le rôle de SDR est de ramener toutes ou certaines parties et fonctions analogiques de la radio au niveau logiciel.

Evolution de la radio matérielle à la radio logicielle



- La flexibilité de SDR lui permet de s'adapter à différents protocoles de radiocommunication, et de répondre au besoin croissant de performance et d’interopérabilité entre systèmes.
- L'objectif de la radio logicielle consiste en une dématérialisation complète de l'interface radio. Elle participe à la tendance globale des circuits électroniques à devenir des circuits à haute densité d'intégration

Ingrédients pour faire du SDR

Antenne + HW + PC/SW

SDR hardware

Les matériels SDR incluent pour la plupart d'entre eux:

- Des field programmable gate arrays (FPGA);
- digital signal processors (DSP),
- general purpose processors (GPP)
- programmable System on Chip (SoC)
- autres processeurs programmables spécifiques à l'application…

SDR hardware

- Aucun choix n'est préférable à l'autre.
- Un tradeoff entre performance, rapidité de calcul, prix et compatibilité avec ce qu'on veut faire!
- Généralement, les processeurs dédiés aux applications de radio logicielle possèdent une architecture hétérogène multi-coeur composée de FPGA(s), DSP(s) ou GPP(s).

Classification des systèmes SDR

Catégorie	Dénomination	Degré de reconfiguration
0	Radio matérielle	Radio qui ne peut pas être modifiée par logiciel ; reconfiguration par échange de composant.
I	Radio contrôlée par logiciel	Reconfiguration limitée à un jeu prédéfini de paramètres (niveau de puissance, interconnexions, ...)
II	Radio définie par logiciel	Contrôle logiciel et reconfiguration des formes d'ondes, fréquence, bande passante, (dé)modulation, détection du signal, paramètres de sécurité, etc.
III	Radio logicielle idéale	Conversion analogique au niveau de l'antenne, du haut-parleur et du microphone ; tout le reste est logiciel.
IV	Radio logicielle ultime	Comprend tout type de trafic et d'informations de contrôle, et supporte la plupart des applications et circuits d'antenne.

SDR HW

Low Cost

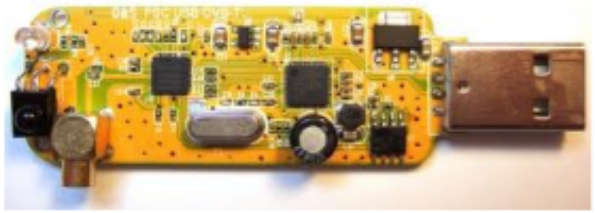
Use the soundcard to for ADC

TX/RX

UHFSDR

SoftRock
Uses the Sound card for ADC

RX



SDR-RTL

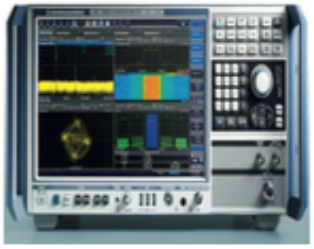
Medium Cost

USRP ~$600

Blade RF ~$400

High End

FlexRadio Systems FLEX-5000A



Rhode+Schwarz
$45,000

SDR HW: que choisir?

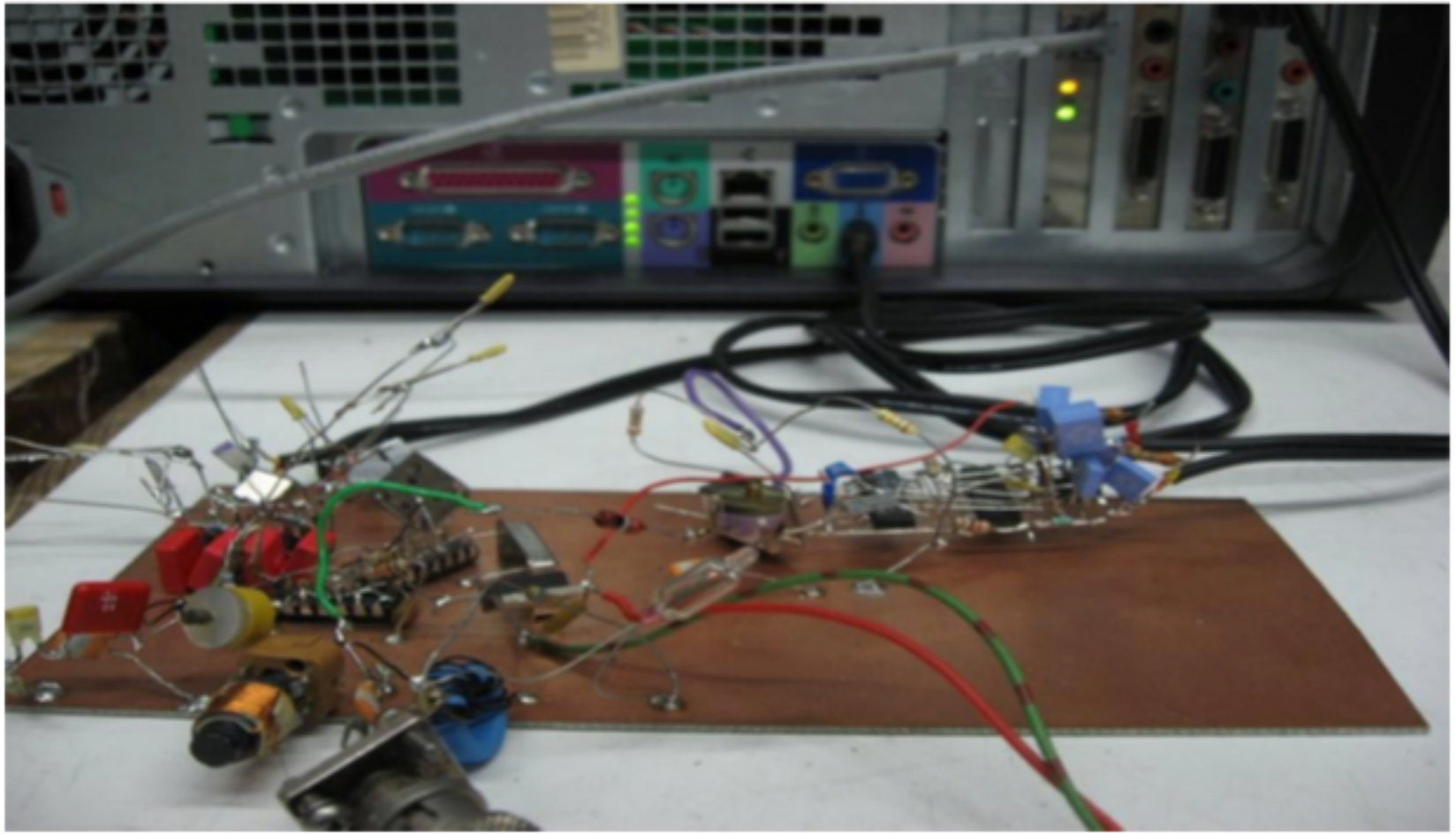
Rhode+Schwarz
$45,000

Or

RTL-SDR
$18

http://www.ebay.com/itm/Newsky-TV28T-v2-USB-DVB-T-RTL-SDR-Receiver-RTL2832U-R820T-Tuner-MCX-Input-/160896092118?pt=LH_DefaultDomain_0&hash=item25762787d6

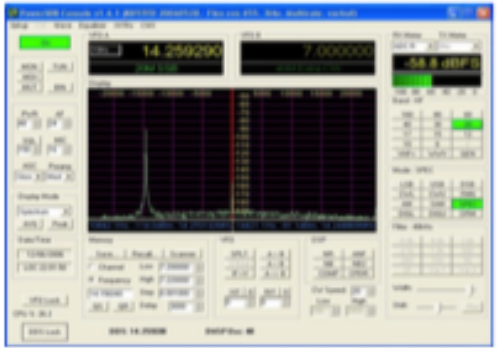
On peut aussi construire le notre…



SDR software

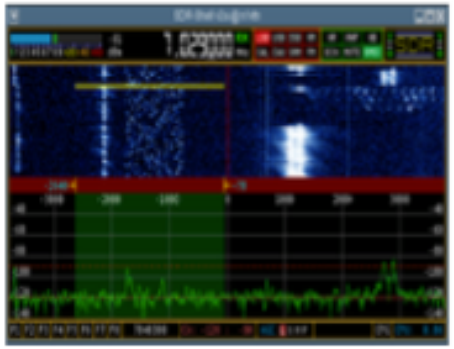
PowerSDR

http://www.flex-radio.com



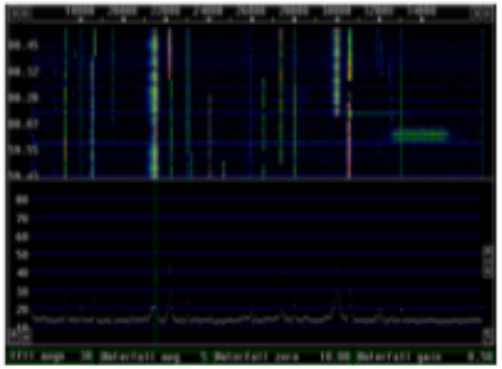
SDR Shell

http://ewpereira.info/sdr-shell



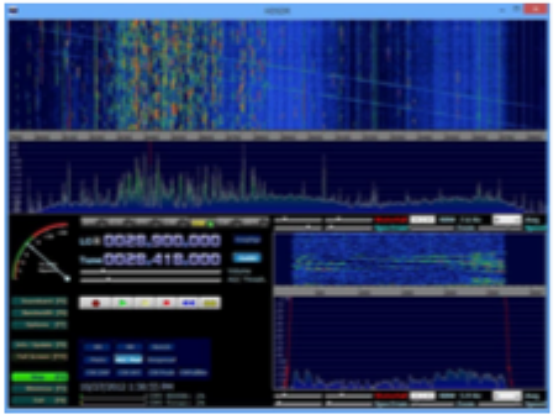
Linrad

http://www.nitehawk.com/sm5bsz/linuxdsp/linrad.htm



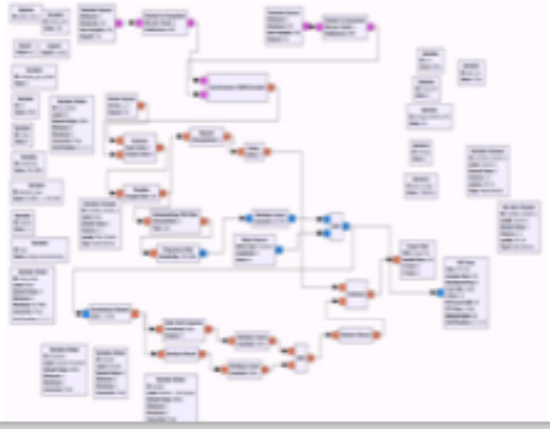
HDSDR

http://www.hdsdr.de/screenshots.html



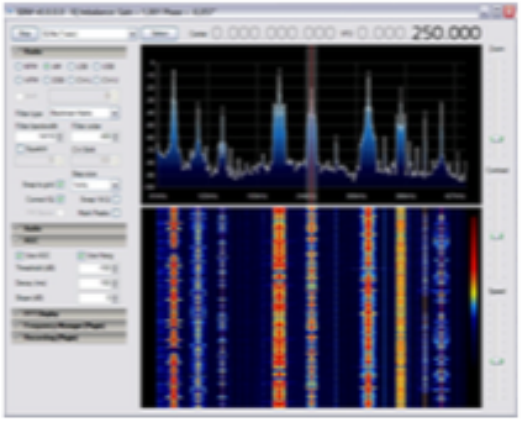
GNU Radio

http://gnuradio.org

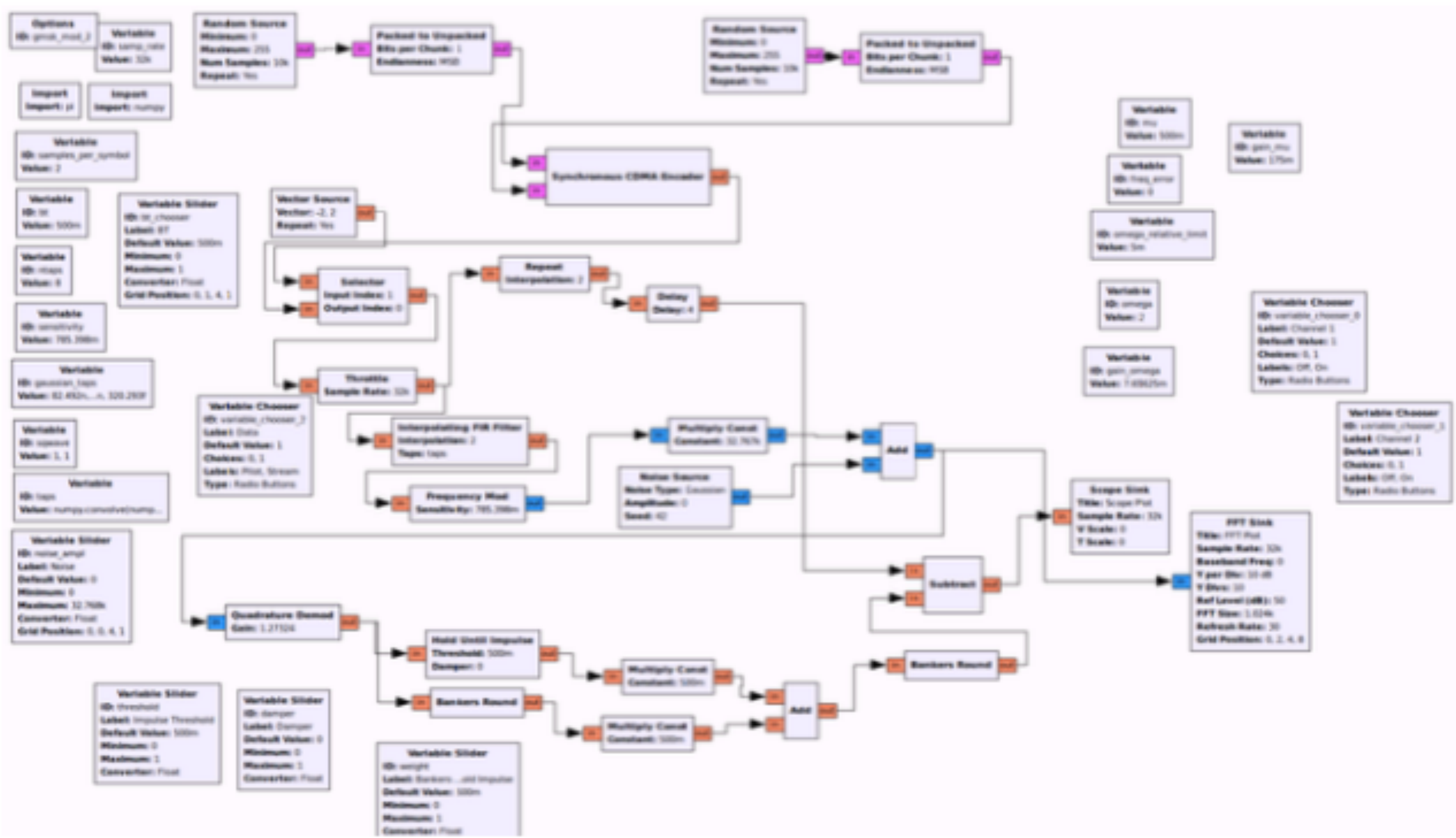


SDR Sharp

http://sdrsharp.com/



GnuRadio


Options
Random Source
Packed to Unpacked
Random Source
Packed to Unpacked
Synchronous CDMA Encoder
Variable Slider
Vector Source
Selector
Repeat
Delay
Throttle
Variable Chooser
Interpolating FIR Filter
Multiply Const
Add
Frequency Mod
Noise Source
Scope Sink
FFT Sink
Subtract
Quadrature Demod
Hold Until Impulse
Multiply Const
Bankers Round
Add
Multiply Const
Bankers Round

Exemple SDR: DSP RX SW

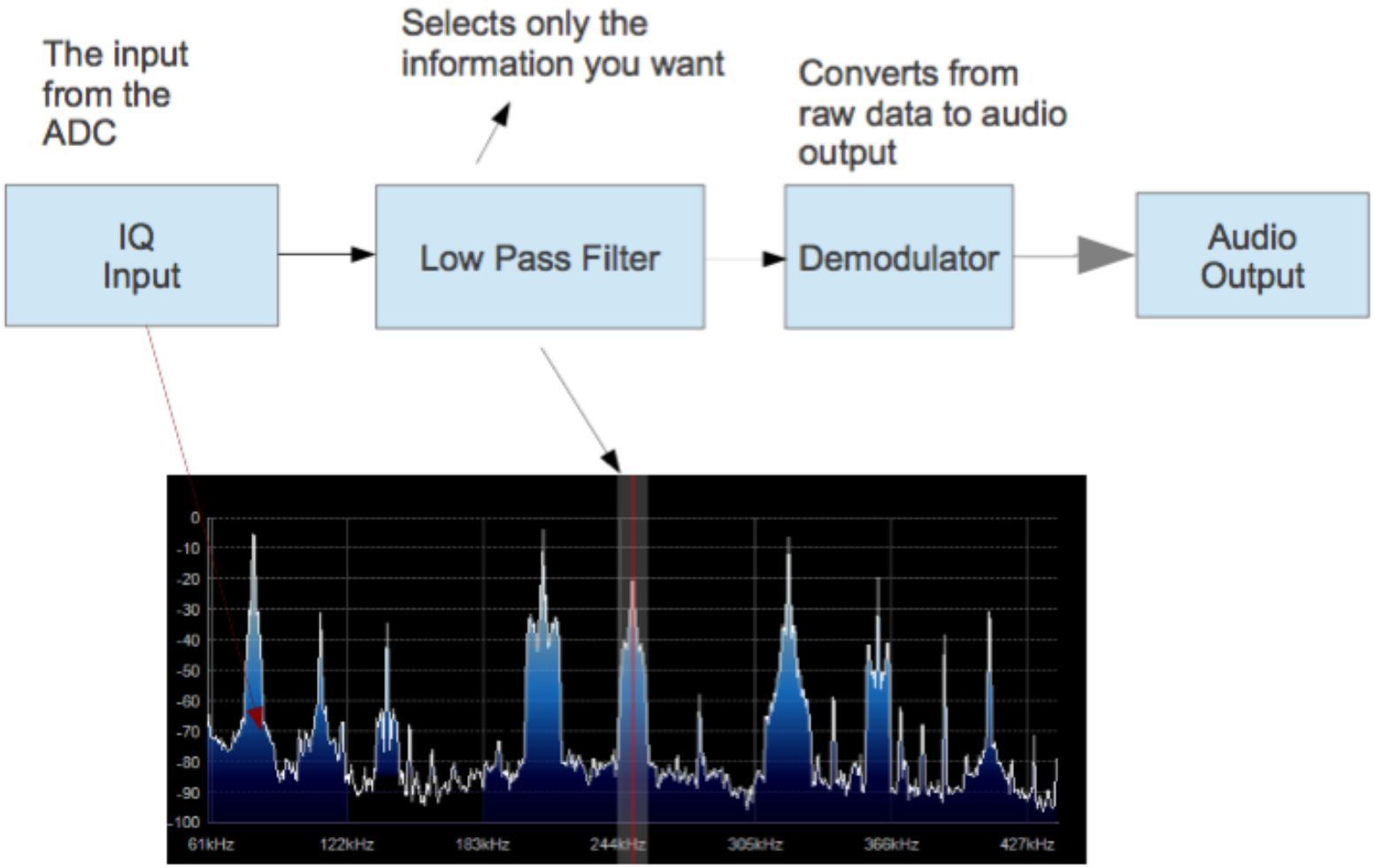


Schéma Récepteur

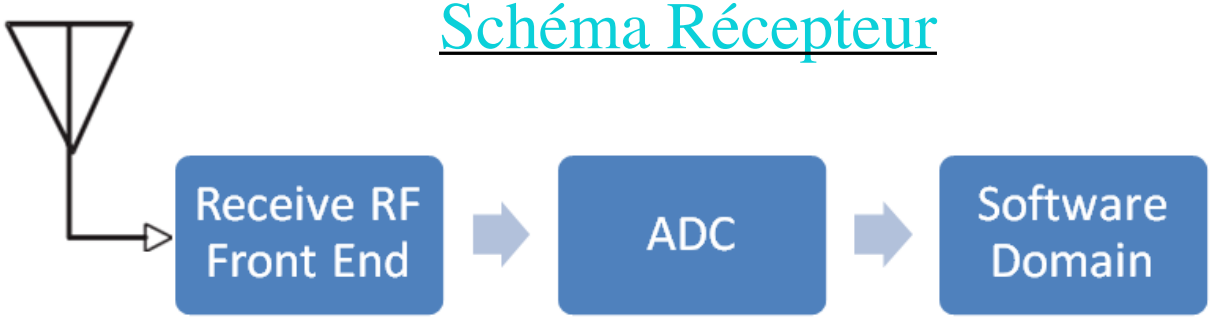
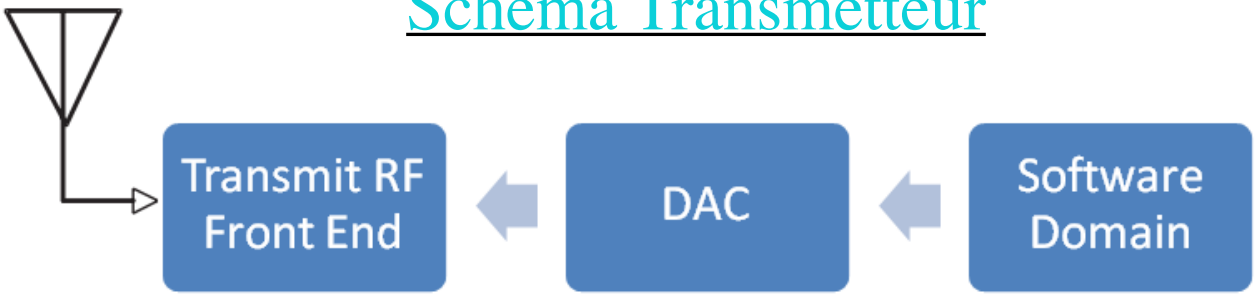


Schéma Transmetteur

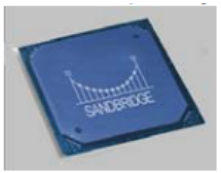


Avantages de SDR

- Pour les équipementiers de systèmes radio et intégrateurs système

- Une famille de « produits» radio à manufacturer en utilisant une architecture de plate-forme commune, permettant une rapide introduction de nouveaux produits dans le marché.

- Un SW peut être réutilisé dans dans plusieurs HW, réduisant ainsi considérablement les coûts de développement.



- Une communauté de développement permettant de réduire les coûts de maintenance et d'exploitation grâce à une supervision à distance et en ligne.

Avantages de SDR

- Pour les fournisseurs de services d'accès radio

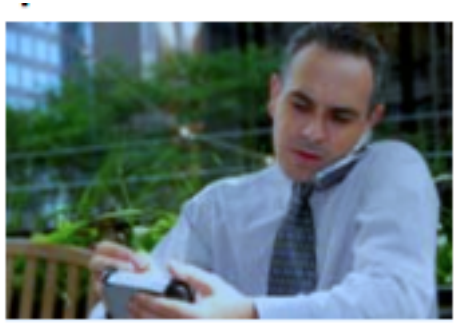
- De nouvelles fonctionnalité peuvent être ajoutées à l'infrastructure existante sans y apporter d'importantes dépenses de modification. Permettant ainsi aux Service Providers de quasi-assurer leur réseaux pour les technologies à venir.

- L'utilisation d'une plate-forme radio commune pour de multiples marchés, réduisant de manière significative les dépenses d'exploitation logistiques.

- Téléchargements de logiciels à distance, à travers lesquels la capacité des SP peut être augmentée, et de nouvelles fonctionnalités génératrices de revenus peuvent y être insérées.

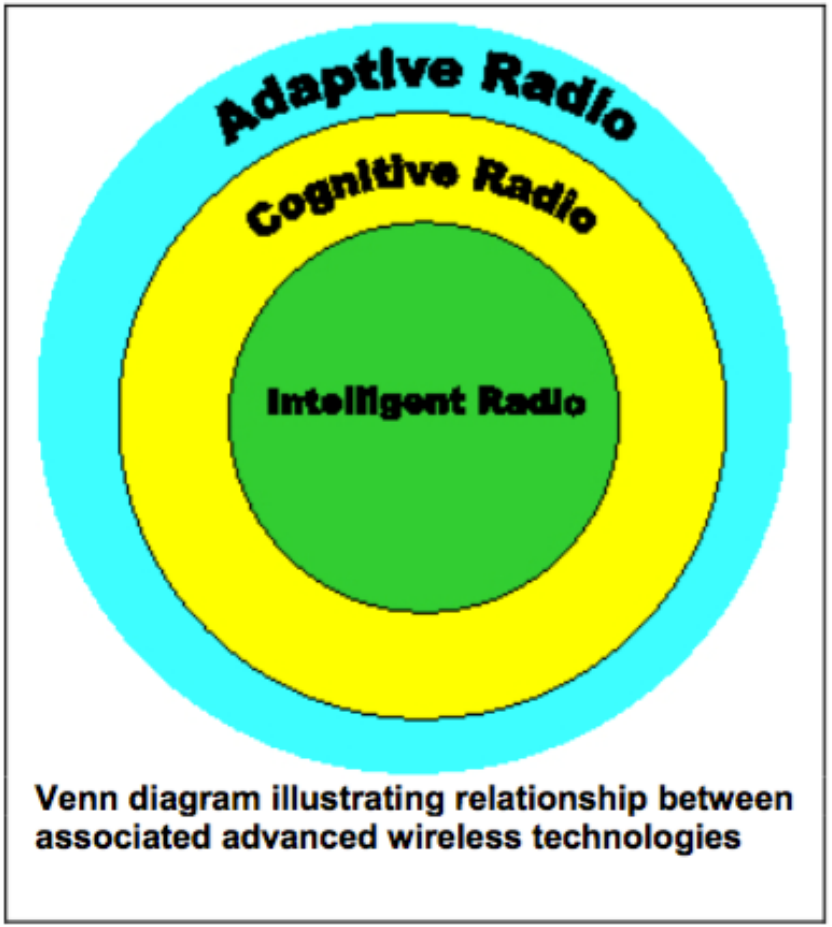
Avantages de SDR

- Pour les utilisateurs (End Users): des voyageurs d'affaires aux soldats sur le champ de bataille.



- Réduire les coûts de communication en offrant un accès sans fil, permettant aux utilisateurs de communiquer avec qui ils ont besoin, quand ils ont besoin et de la manière appropriée.

Autres applications de SDR (domaines de recherche)



Venn diagram illustrating relationship between associated advanced wireless technologies

Adaptive Radio

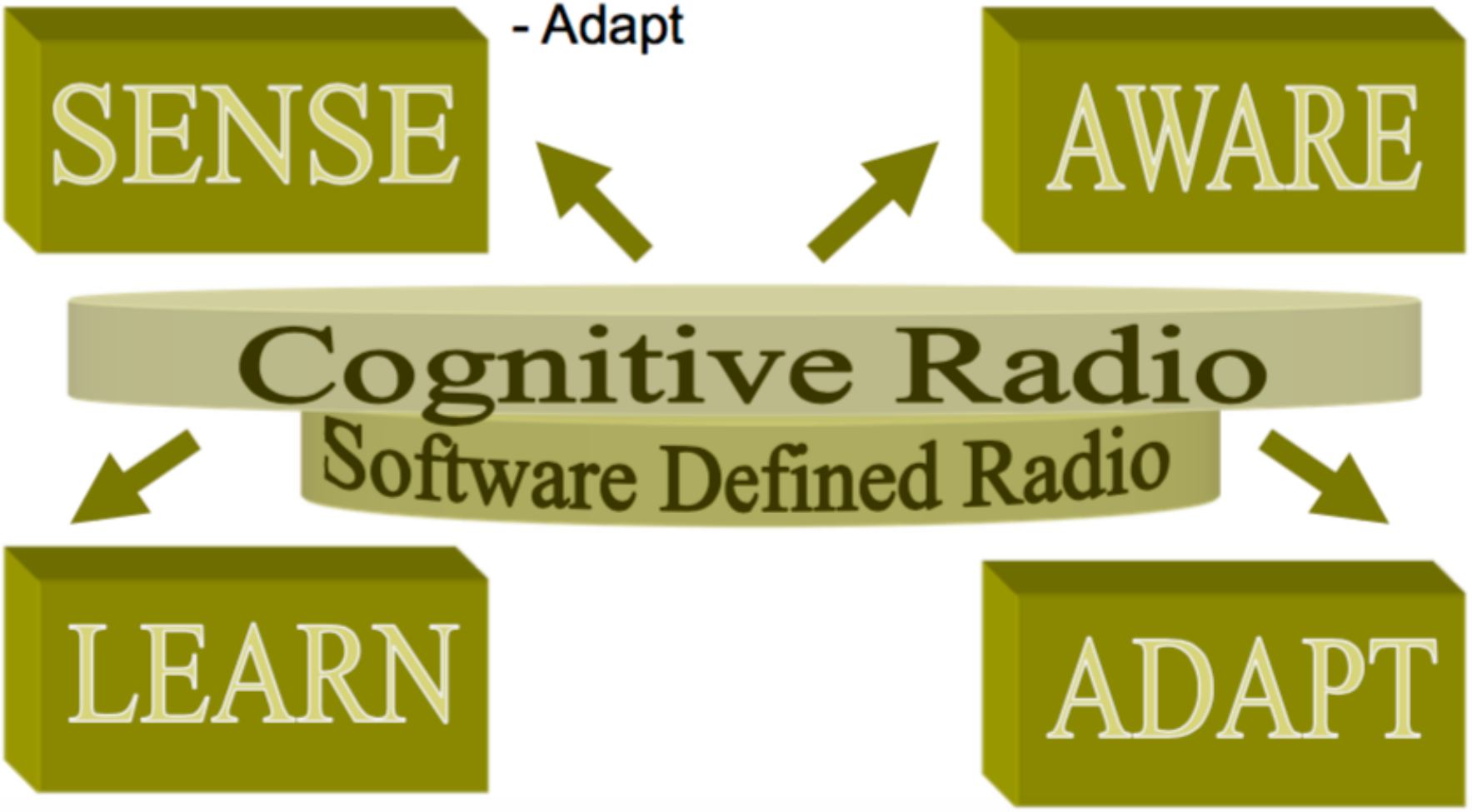
- Les systèmes de communication ont les moyens de surveiller leur propre performance et modifier leurs paramètres de fonctionnement pour améliorer cette performance.
- L'utilisation des technologies SDR dans un système de radio adaptative permet plus de degrés de liberté dans l'adaptation, et donc des niveaux de performance plus élevés et une meilleure qualité de service dans un lien de communication.

Cognitive Radio

- La radio cognitive est la radio dont les systèmes de communication sont conscients de leur état interne et de l'environnement, tels que l'emplacement et l'utilisation sur le spectre de fréquences RF à cet endroit.

- Adaptive, multi-dimensionally aware,
- autonomous radio (system) that
- learns from its experiences to
- reason, plan, and decide future
- actions to meet user needs”

- To have awareness
- Create Knowledge
- Make decisions
- Adapt



Cognitive Radio, Software Defined Radio, and Adaptive Wireless Communication Systems

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WCSP Group

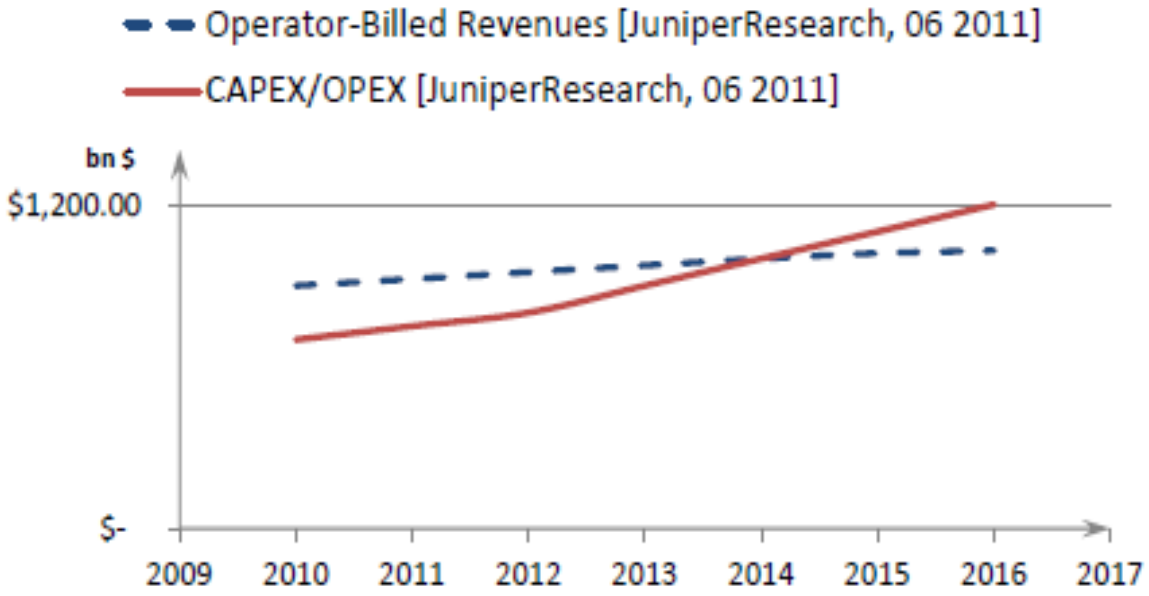
Radio intelligente

- La radio intelligente est la radio cognitive qui est capable du machine learning (apprentissage machine).
- Cela permet à la radio cognitive d'améliorer les façons dont elle s'adapte à l'évolution de performance et d'environnement afin de mieux servir les besoins de l'utilisateur final.

- Ces types de Radio - Radio adaptative, radio cognitive et radio intelligente - ne définissent pas nécessairement une seule pièce d'équipement, mais comprennent un ensemble d'équipements répartis sur tout le réseau.

C-RAN

- Traditional RAN is outdated and too expensive for operators to keep.
- Causes:
  - difficulty to build more BSs (rise of CAPEX and OPEX),

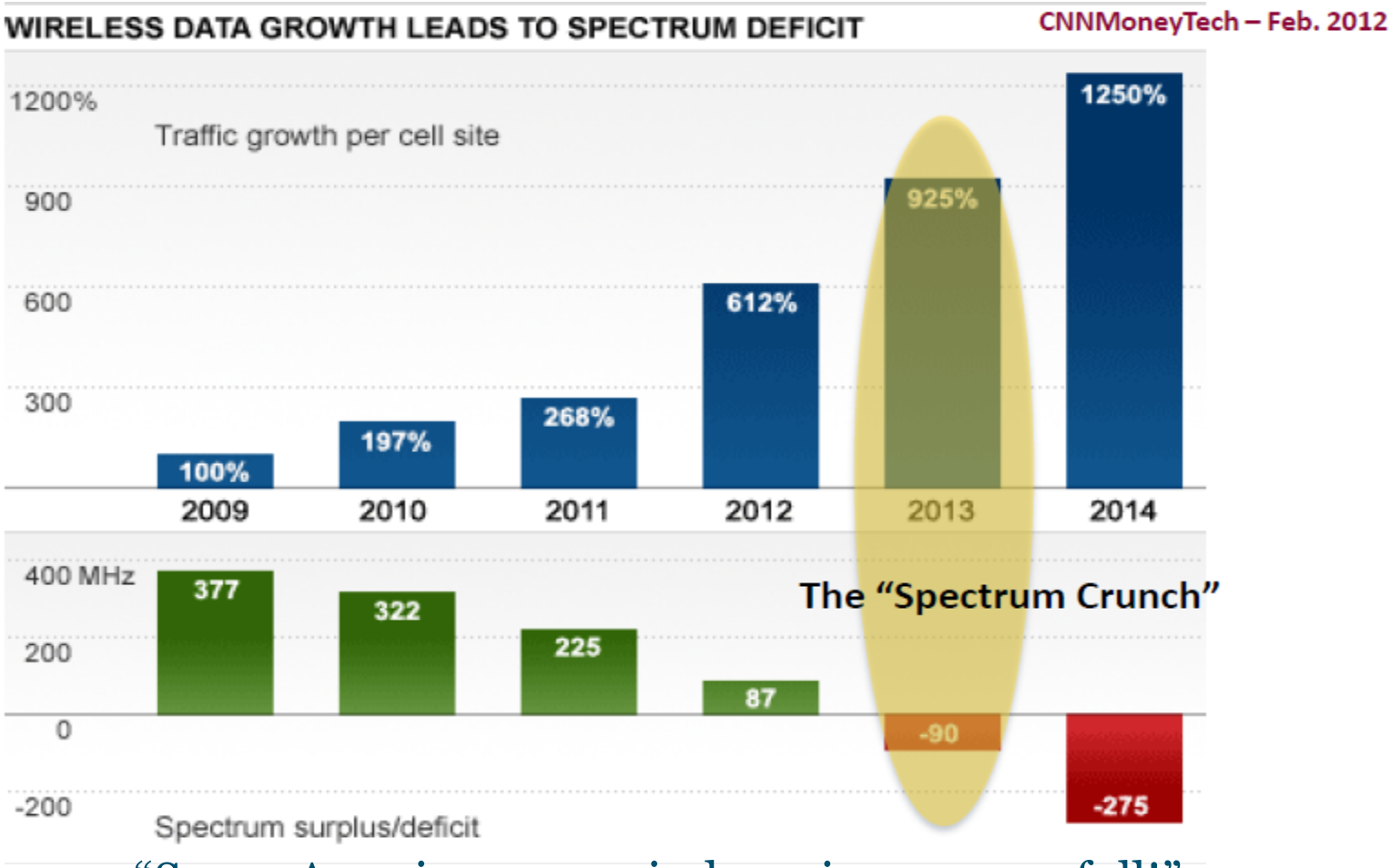


Costs vs revenues is mobile networks

Traditional architecture

C-RAN definition

Centralized architecture



"Sorry, America: your wireless airwaves are full!"

Traditional architecture | C-RAN definition | Centralized architecture

- Difficulty to share BS's processing powers and increasing the spectrum efficiency,

- Traditional RAN lacks the efficiency to support centralized interference management required by future HetNets,

- Purchasing platforms to build in BSs causes operators complex and costly plans for network expansion and upgrading.

Traditional architecture | C-RAN definition | Centralized architecture

Deploying One Macrocell	Effort (MD – Man Day)
New site verification	**1**
On site visit: site details verification	0.5
On site visit: RF survey	0.5
New site RF plan	**2**
Neighbors, frequency, preamble/scrambling code plan	0.5
Interference analyses on surrounding sites	0.5
Capacity analyses	0.5
Handover analyses	0.5
Implementation on new node(s)	**0.5**
Field measurements and verification	**2**
Optimization	**2**
Total activities	**7.5 man days**

- 1 M BSs in 2015
- 7.5 M Man Days = 20.6k Man Years
- Exorbitant costs
- Where to find so many engineers?

Traditional architecture

C-RAN definition

Centralized architecture

Urgent need to create a new low cost RAN with high spectral and energy efficiency.

Traditional architecture

C-RAN definition

Centralized architecture

Cloud computing based RAN

Clean

Centralized processing

Collaborative radio

Traditional architecture | C-RAN definition | Centralized architecture

- C-RAN is a network architecture where baseband resources are centralized in a virtual pool.

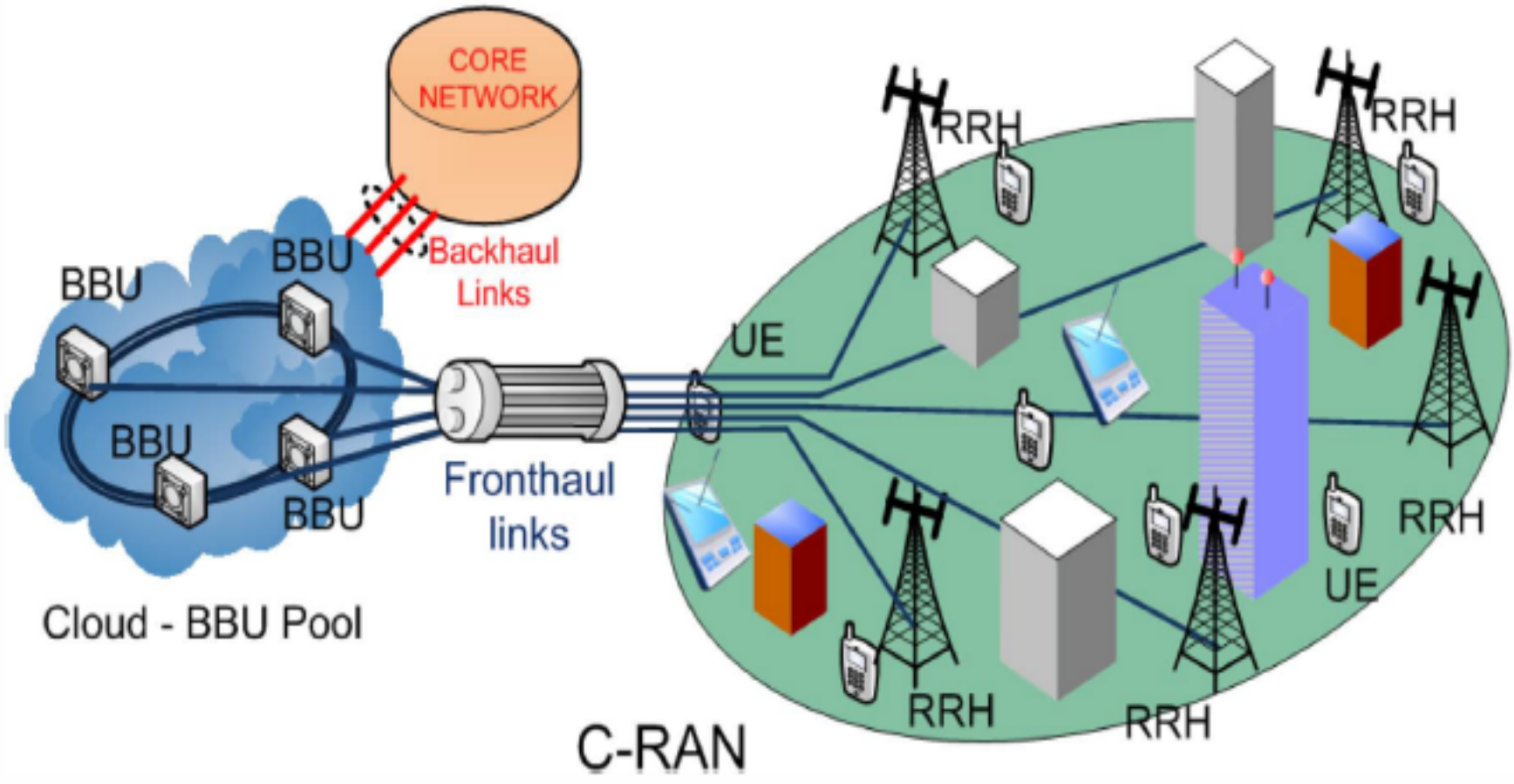
➢ **The C-RAN architecture is based on:**

- A centralized base-band pool processing regrouping many **Baseband units (BBUs).**
- Simple, light-weight radio units with antenna equipped called **Remote Ratio Heads (RRH)**, or **Radio Access Units (RAU).**
- A high bandwidth low-latency optical network which connects the RRHs to the BBU pool.

Traditional architecture

C-RAN definition

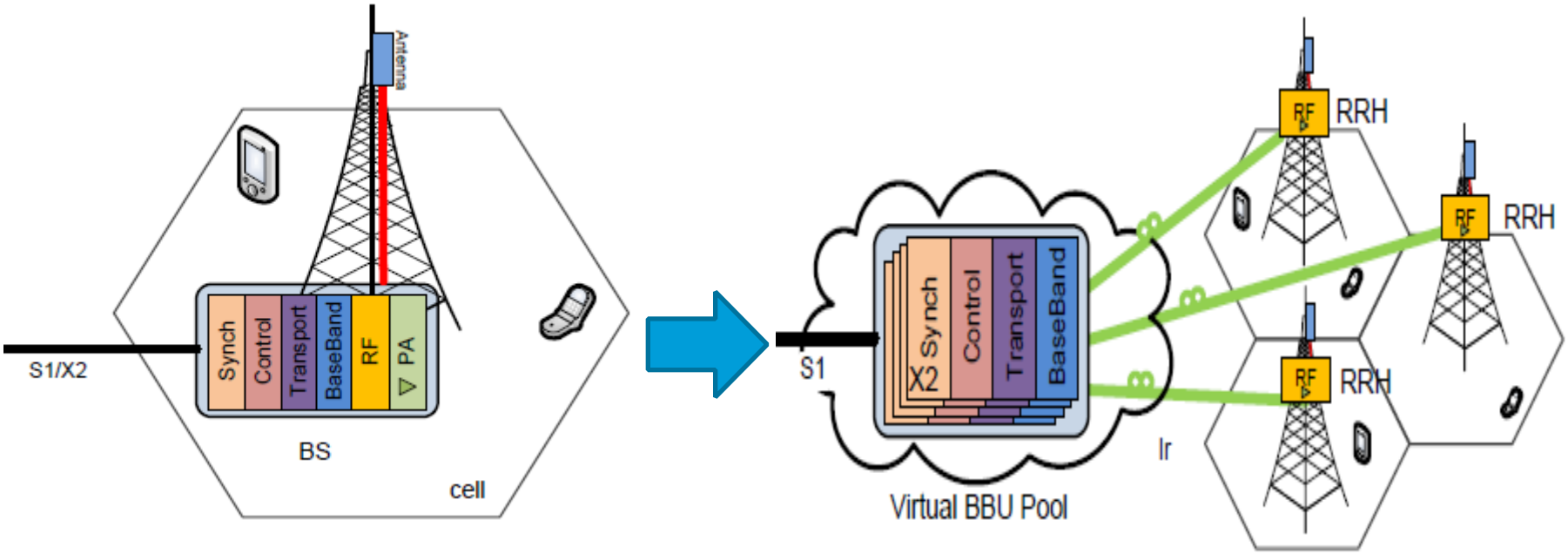
Centralized architecture



Traditional architecture

C-RAN definition

Centralized architecture



Traditional RAN

C-RAN

Fiber – Digital BaseBand

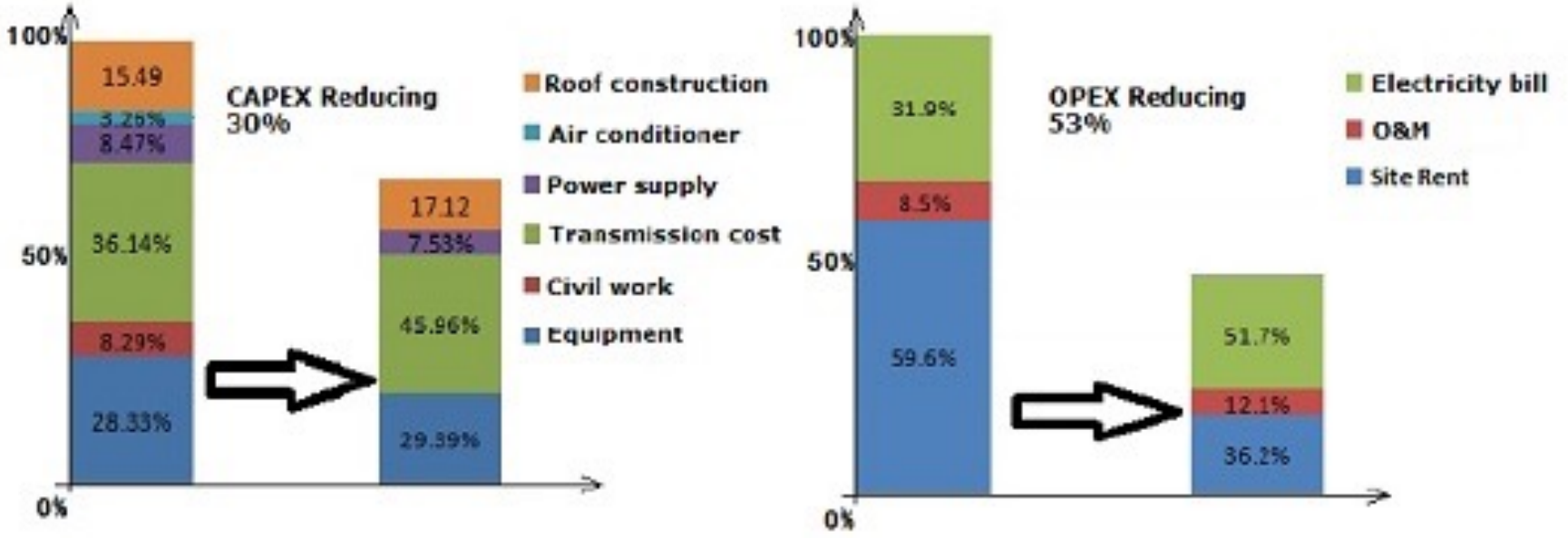
Coax cable – RF

Adaptability | **Energy & cost savings** | **Ease in upgrades**

- ✓ Resource Virtualization/Cloudification: resources in C-RAN are aggregated on a pool level and can be flexibly allocated on demand.
- ✓ BBUs can work together in a large physical BBU pool and they can easily share the signaling, traffic data and channel state information (CSI) of active UE's in the system.
- ✓ Hence, by doing a proper load balancing of the BBUs, network capacity can be enhanced and the C-RAN can adapt itself to non-uniform traffic during the day (day/night traffic).
- ✓ Network coverage can be improved by adding new RAUs the BBU pool, which increases network flexibility.

Adaptability | Energy & cost savings | Ease in upgrades

- ✓ C-RAN provides low-cost and high performance green network architecture to operators with low CAPEX and OPEX.
- ✓ Civil work on remote sites can be reduced by gathering equipment in a central room, which contributes to additional OPEX savings.



Adaptability

Energy & cost savings

Ease in upgrades

- ✓ C-RAN appears as an efficient way to help network construction with the advantages of reducing interference, saving cost, speeding up site construction and lowering down difficulties in site selection.
- ✓ Eco-friendly RAN: possibility to turn off or to lower the power consumption of virtual BS when the processing power is not needed (night times).
- ✓ Environment issue: RRU of low power consumption (small cells) and antennas with smaller size can reduce the public concern on the radio radiation.

Adaptability

Energy & cost savings

Ease in upgrades

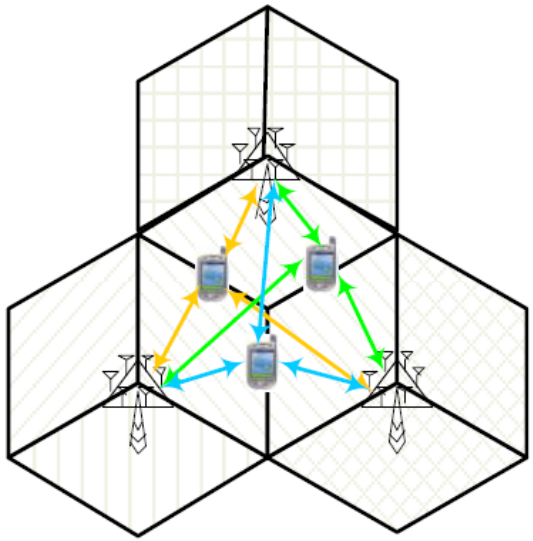
- ✓ The processing capacity can be enhanced with the upgrade of the BBU pool to lessen the network load grow.
- ✓ Advanced Technology Facilitation: many technologies that are difficult to implement in traditional architectures, especially joint processing and cooperative radio (CoMP), will become viable in a C-RAN context.
- ✓ In C-RAN BBU pool, through resource cloudification, a BBU is of *soft form*; the capability of a soft BBU can be dynamically reconfigured and adjusted. In this way, resource utilization efficiency can be greatly increased.

Radio over low cost fiber | Cooperative Tx/Rx | Virtualization | BBU pool interconnection

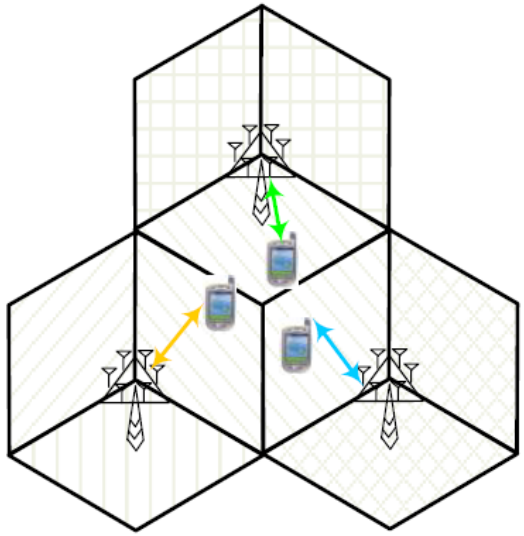
- **A need for high bandwidth, strict latency and low cost transport network.**
- Digital baseband signals transported between RAUs and BBUs bring up a significant overhead. Therefore the installation and operation of transport network must be wisely planned.
- The RAUs data should be transmitted in a optical link with at least 10 Gbps with strict requirements on transmission latency.
- The cost of leasing the fiber connection may increase CAPEX.

Radio over low cost fiber | Cooperative Tx/Rx | Virtualization | BBU pool interconnection

- CoMP (coordinated multipoint) is used to send and receive data to and from a UE from several points to increase cell average spectrum efficiency and cell-edge user throughput .



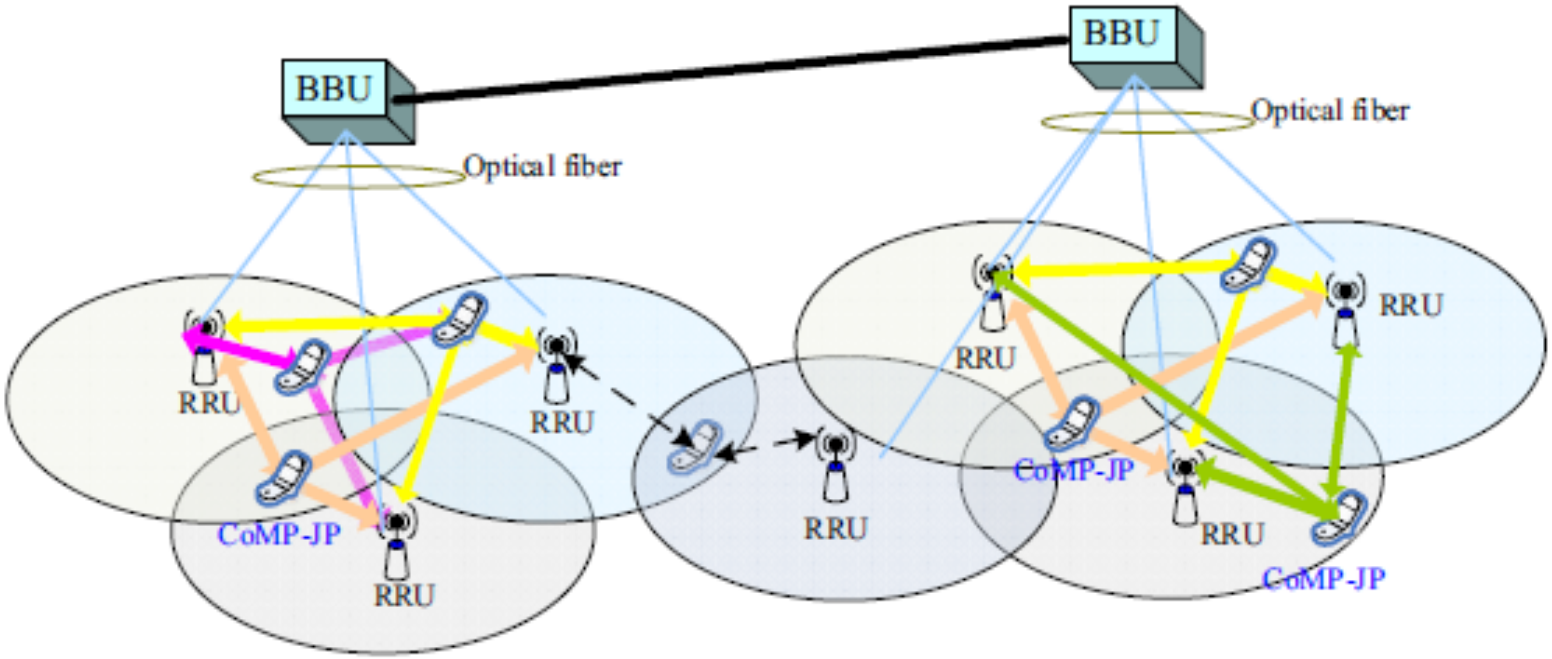
Joint processing



Coordinated beamforming

Radio over low cost fiber | Cooperative Tx/Rx | Virtualization | BBU pool interconnection

- Cooperation between BBUs is needed to support CoMP for sharing the user data, scheduling at the base station and handling channel feedback information to deal with large interference.

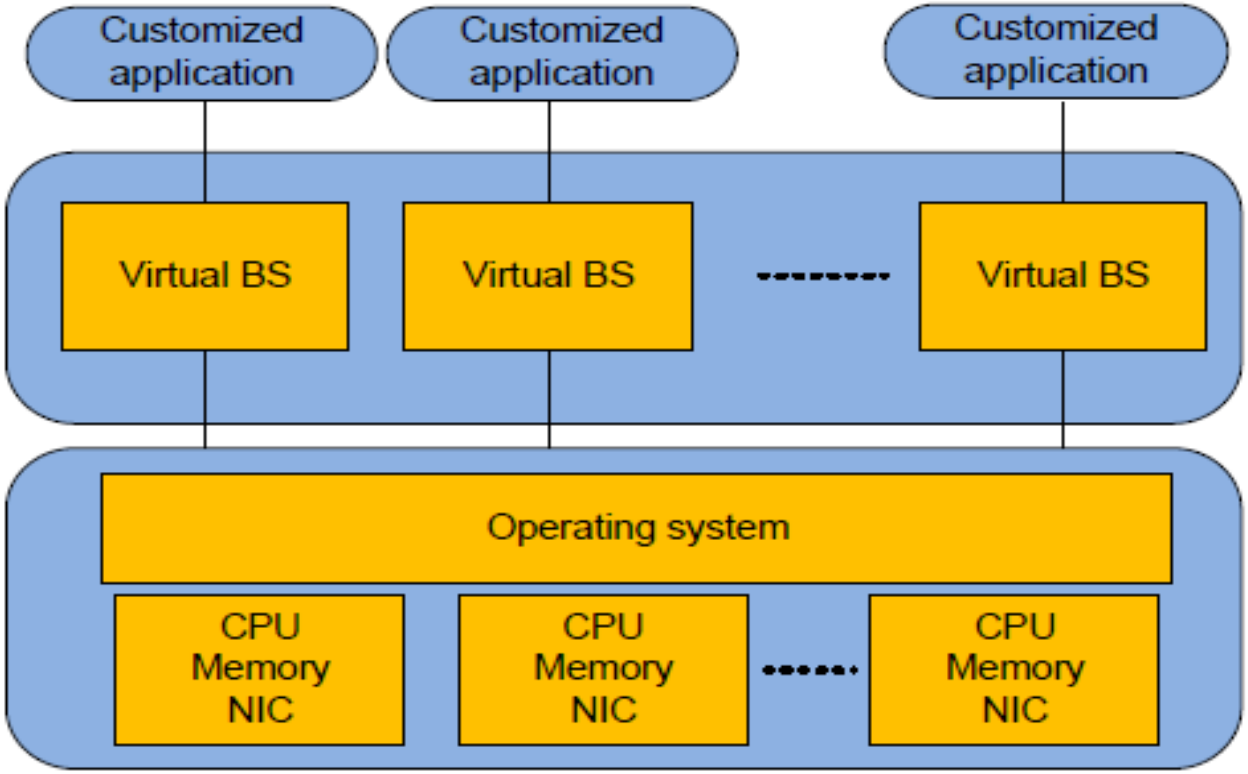


Radio over low cost fiber | Cooperative Tx/Rx | Virtualization | BBU pool interconnection

- **Advanced cooperative transmission/reception:** Need to develop cooperative multi-point processing algorithms by sharing both end-user data and UL/DL channel information among virtual BSs.
- The interface between virtual BSs to carry this information should support high bandwidth and low latency to ensure real time cooperative processing.
- The information exchanged in this interface includes: end-user data package, UE channel feedback information, and virtual BS's scheduling information. Therefore, the design of this interface must meet the real-time joint processing requirement with low backhaul transportation delay and overhead.

Radio over low cost fiber | Cooperative Tx/Rx | **Virtualization** | BBU pool interconnection

- A need for a virtualization technique for group processing between VBSs entities and sharing of resources among multiple operators.



Radio over low cost fiber | Cooperative Tx/Rx | **Virtualization** | BBU pool interconnection

- Dynamic processing capacity allocation is necessary to deal with a dynamically changing cell load.
- SDN and NFV are candidates for C-RAN application and dynamic resource allocation between VBSs.
- Despite the conceptual simplicity of virtualization, the actual implementation is more difficult. Wireless communication is distinct from IT data centers in that wireless communication has extremely strict requirements for real-time processing.

Radio over low cost fiber

Cooperative Tx/Rx

Virtualization

BBU pool interconnection

IT- Cloud computing

- Mbps range for Client/BS data rate (low activity)
- Tens of ms for latency
- Long Life time of information
- s range allowed for recovery time
- Thousands, even millions of clients per centralized location

Telecom – Cloud RAN

- Gbps range for Client/BS data rate (constant stream)
- < 5 ms for latency
- Extremely short Life time of information
- ms range to avoid network outage
- Tens, may be hundreds of clients per BBU.

Radio over low cost fiber | Cooperative Tx/Rx | Virtualization | **BBU pool interconnection**

- Need of a reliable, low cost switch network with low latency, high bandwidth with an extensible topology that interconnects all BBUs in the centralized pool.
- Any signal coming from any RRH can be routed to the BBU in the pool (any individual BBU failure won't affect the functionality of the system).
- Co-location of many BBUs requires special security and resilience mechanisms.

C-RAN deployment

- China Mobile, together with its industry partners - **IBM, ZTE, Huawei, Intel, Datang China Mobile, France Telecom Beijing Research Center, Beijing University of Post and Telecom and China Science Institute** developed a General Purpose Processor based C-RAN prototype supporting GSM, TD-SCDMA and TD-LTE.
- The prototype is running on Intel processor-based servers. L1, L2 and L3 of GSM and TD-SCDMA as well as L1 TD-LTE are supported.
- Future plans cover implementing L2 and L3 of TD-LTE and LTE-A features like CoMP.

C-RAN deployment

- Korea Telecom announced at the end of 2011 their plans on the first commercial deployment of C-RAN. It will cover LTE, 3G, WiMAX, and Wi-Fi technologies.
- In Japan, DoCoMo has announced their plan of C-RAN implementation.
- C-RAN projects have been initiated in NGMN and EU commission's 7^{th} Framework Programme.
- Many other operators and vendors (KT, SKT, Orange, Intel, ZTE, Huawei and Alcatel-Lucent) are helping building the C-RAN ecosystem.

Conclusions

- C-RAN and BBU centralization can support existing 2G, 3G, 4G systems and future wireless communication standards.
- The main objective of C-RAN deployment in 2G and 3G is to demonstrate the deployment benefits of centralization, speed-up of site construction , increase of coverage and power consumption reduction.
- For 4G LTE, C-RAN can address the issue of ICI with the use of Coordinated Multi-Point transmission/reception (CoMP), that is one of the candidate techniques for LTE-A systems to increase the cell average and cell edge user throughput.

Conclusions

- C-RAN is not only a new network infrastructure, but also a combination of introducing a serial of new technologies in this new infrastructure. Thus, the deployment of C-RAN must be a well-planned, step-by-step process.
- On the road towards complete C-RAN realization, there lie major two challenges: efficient front-haul solutions to centralization and virtualization implementation to realize resource cloudification.

Thank you!

Questions?