ARIADNE

Newsletter

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ARIADNE - Artificial Intelligence Aided D-band Network for 5G Long Term Evolution – is a three years Horizon 2020 project started in November 2019, aiming to enable spectral e¬fficient, high-bandwidth, and intelligent wireless communications.

SECOND ARIADNE PRESS RELEASE

ARIADNE specified its system model

After one year on its life time, the ARIADNE project specified its system model as base for future investigations which will be carried out within the project scope. An analysis of the D-band directional link, including consideration of suitable channel modelling approaches, possible ways forward in performance evaluation, and preliminary studies on appropriate application of machine learning techniques in this context has been concluded. Furthermore, bases for application of Reconfigurable Intelligent Surfaces and reconfigurable antennas for D-Band have been laid down.

ARIADNE Vision and System Concept

With the aspiration to transform the current (5G) wireless thinking from focusing on "local" network improvements (e.g. isolating the radio access level or the resources management level etc.), to realizing a longer term vision of pervasive mobile virtual services, through a network managing computing and connectivity functions in an integrated way, ARIADNE envisions to bring together a novel high frequency advanced radio architecture and an Artificial Intelligence (AI) network processing and management approach in a unified system beyond 5G concept.

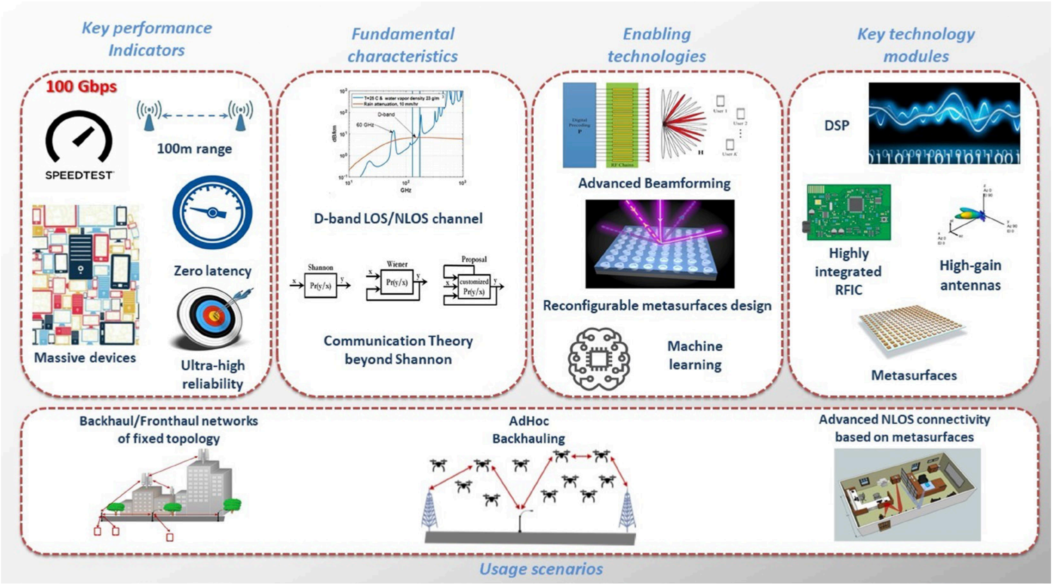
The vision of ARIADNE is to investigate, theoretically analyse, design, develop, and showcase in a proof of concept demonstrator, an innovative wireless communications concept addressing networks beyond 5G, in which ultra-high spectral efficient and reliable communications in the bandwidth-rich D-band can be dynamically established and reconfigured by Machine Learning (ML)-based design and intelligent network management, in both "Line of Sight" (LOS) and "Non-Line of Sight" (NLOS) environments.

The ARIADNE System Concept

Sustaining a flexible and ubiquitously available 100 Gbps network for backhaul and access in systems beyond 5G will require the exploitation of higher frequency bands, the adoption of novel hardware technologies and advanced materials and the rethinking of Communication Theory framework and traditional design principles and architectures.

In this way, in the beyond 5G era, the conventional system concept of a 5G network as a universal resources (physical and virtual) manager will be transformed into the system concept of a fully adaptive (to environmental characteristics, volatility and user requirements), power-efficient distributed computer and highly reliable connectivity provider.

Bringing to fruition the notion of AI-aided D-band wireless beyond 5G networks entails the challenges of devising a flexible and powerful ML-based wireless network optimisation framework, introducing novel propagation and channel modelling principles and a revolutionary communication theory approach. These include beamforming antenna arrays, metasurface-based intelligent materials, RF-frontends, baseband processing, medium access control protocols, ML-based resources and network management, as well as devising a suitable performance evaluation framework defined by the appropriate critical use cases and relevant performance metrics.



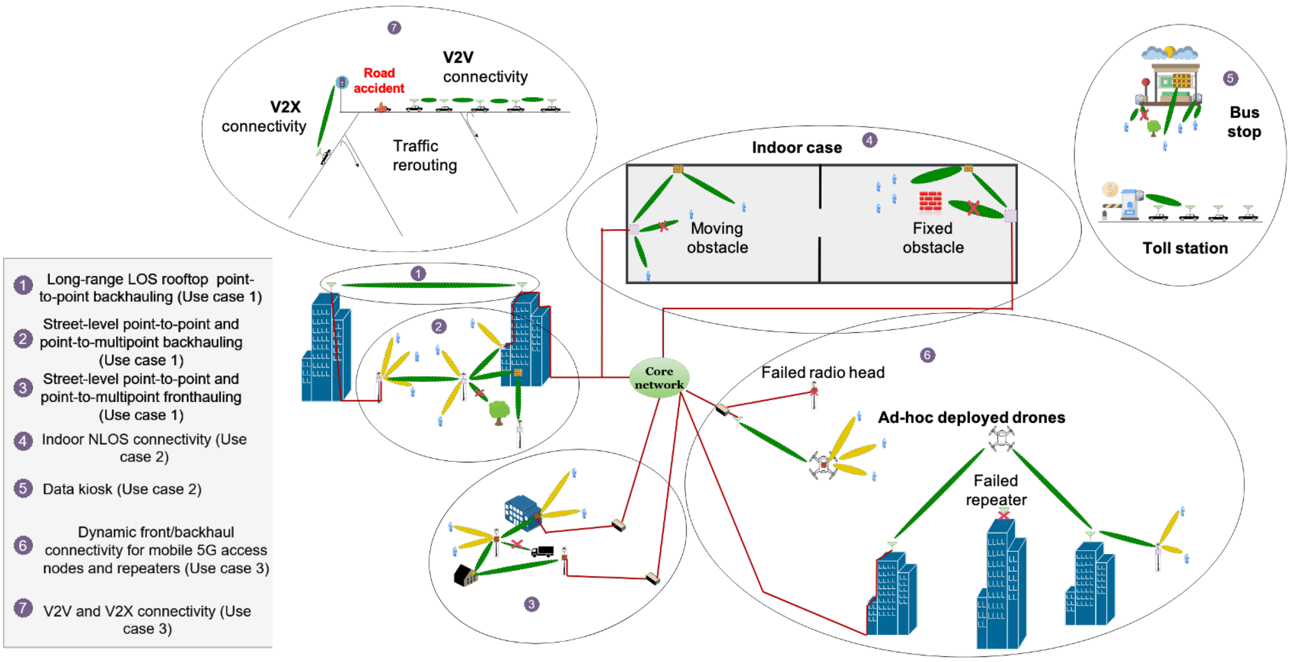
In particular, the ARIADNE approach will be established, developed and evaluated based on its three pillars:

- PILLAR I: D-band for 100 Gbit/s reliable wireless connectivity, by means of advanced, power-efficient transceiver design
- PILLAR II: Communications beyond the Shannon paradigm, by means of metasurfaces for NLOS/obstructed LOS connectivity
- PILLAR III: Artificial Intelligence based wireless system concept, by means of ML approaches

These three ARIADNE pillars represent the main building blocks of the ARIADNE network architecture, which are jointly and optimally combined to successfully address the following its seven major Key Performance indicators (KPIs):

- **Aggregate throughput** of wireless access for any traffic load/pattern (100 Gbps)
- **E2E throughput** in all relevant usage scenarios, backhaul/fronthaul, adhoc backhaul, NLOS/obstructed (100 Gbps)
- E2E **latency** minimisation ('zero' latency)
- **Coverage** of the D-band link (100m outdoors)
- Connectivity **Reliability** for massive number of nodes ('always' available)
- **Energy efficiency** (energy consumption reduction by 10x compared to 5G)
- **Complexity reduction** (10x compared to 5G)

The vision of ARIADNE is to investigate, theoretically analyze, design, develop, and showcase in a proof-of-concept demonstrator an innovative wireless communications concept addressing networks beyond 5G, in which ultra-high spectral efficient and reliable communications in the bandwidth-rich D-band can be dynamically established and reconfigured by Machine Learning (ML)-based design and intelligent network management. To realize this vision, ARIADNE focuses carefully devised use cases, which reflect the B5G requirements and expectations.



On D-band directional link analysis

The high frequency systems, such as D-band, suffer from large path losses requiring utilization of high gain antennas, where if the line-of-sight is available traditional beamforming at the transmitter and receiver sides can help with mitigating the channel losses and provides ability for tracking mobile users. In the non-line-of-sight situations, the D-band systems can benefit by applying Reconfigurable Intelligent Surfaces, allowing intelligent manipulation of radio propagation towards the mobile user as required.

Propagation aspects

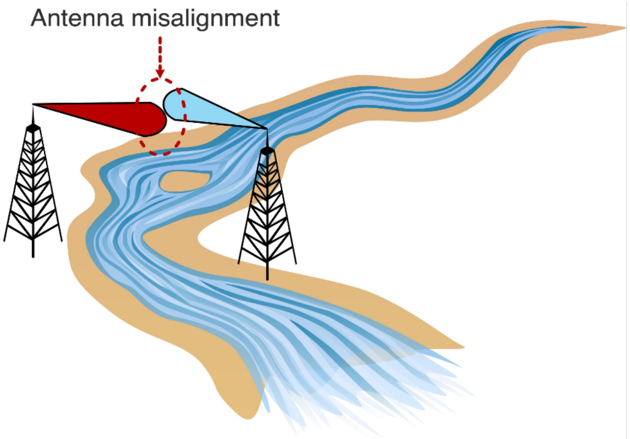
One important aspect of the ARIADNE project is to explore radio propagation via Reconfigurable Intelligent Surfaces (RISs)that are expected to significantly increase the received signal power in non-line-of-sight (NLOS) situations where line-of-sight (LOS) path is blocked.

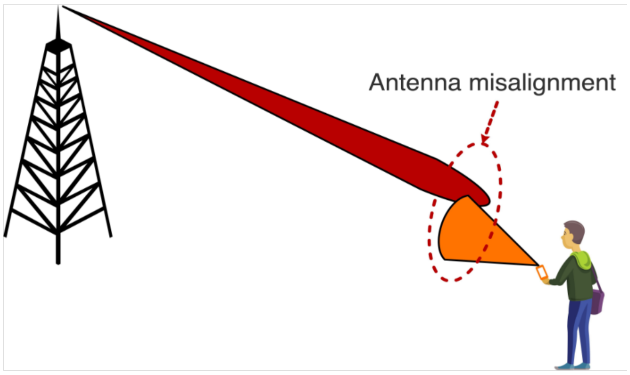
However, with or without RIS, transmission in the high frequency bands (for D-band beyond 100 GHz) requires highly directional antennas to provide enough gain to overcome large propagation losses in the channel. On the other hand, due to the decreasing electric size of antennas as a function of frequency, D-band suffers from high path losses even on LOS path.

As a consequence, high gain antennas have to be used to compensate the losses while also allowing multiple-input multiple-output (MIMO) communications by applying beam steering. In practice, the antennas are not always stationary even in static backhaul/fronthaul configurations, e.g. due to environmental effects such as wind, small structure deformation (even earthquakes), or stochastic tracking estimation errors.

This is not a major problem at lower frequencies, but the D-band high gain antennas are very sensitive to misalignment. This causes a need for accurate and efficient channel estimation to constantly update the beamformers in order to minimize the beam misalignment and maintain sufficient link conditions.

Mobile users, furthermore, require novel beam tracking algorithms to estimate the user position to ensure maximum gain regardless of the user movement patterns.





Reconfigurable Intelligent Surfaces

The RISs can be realized in different ways, for instance, by:

- utilizing large phased antenna arrays.
- utilizing metasurfaces made of metamaterials.

The both solutions aim at the same goal, to modulate the incoming and thereafter reflected electromagnetic waves in order to steer the reflected wave. The wanted reflection properties are obtained by individually controlling the RIS elements or the entire metasurface substructures. Knowing their behavior exactly, RIS steering algorithms canensure maximum beamforming gain and give the best possible transmission conditions.

Machine learning aspects

Application of Machine Learning (ML) techniques in various aspects of wireless communications is growing and relies on its strength to solve complex problems, especially where a model of the phenomenon being learned is too complex to derive it analytically. For example, one of the key issues in communications is to accurately predict the channel parameters, where the traditional approach is to collect a tremendous amount of channel measurement data and then draw up suitable channel models using statistical methods. Here, applying predictive methods has a significant potential to minimize the complexity and improve the accuracy by predicting the channel modelling parameters, such as path loss, carrier phase shifts, etc. Also, resource allocation, user scheduling, energy efficiency, precoding and signal detection, massive MIMO, beamforming, etc. are the optimization challenges which might be effectively solved by application of the ML techniques. Recent trends in research are emerging towards deep learning algorithms, which possess inherent ability in tackling some of these issues and are often used to predict channel characteristics for massive MIMO channels.

Intermediate conclusions

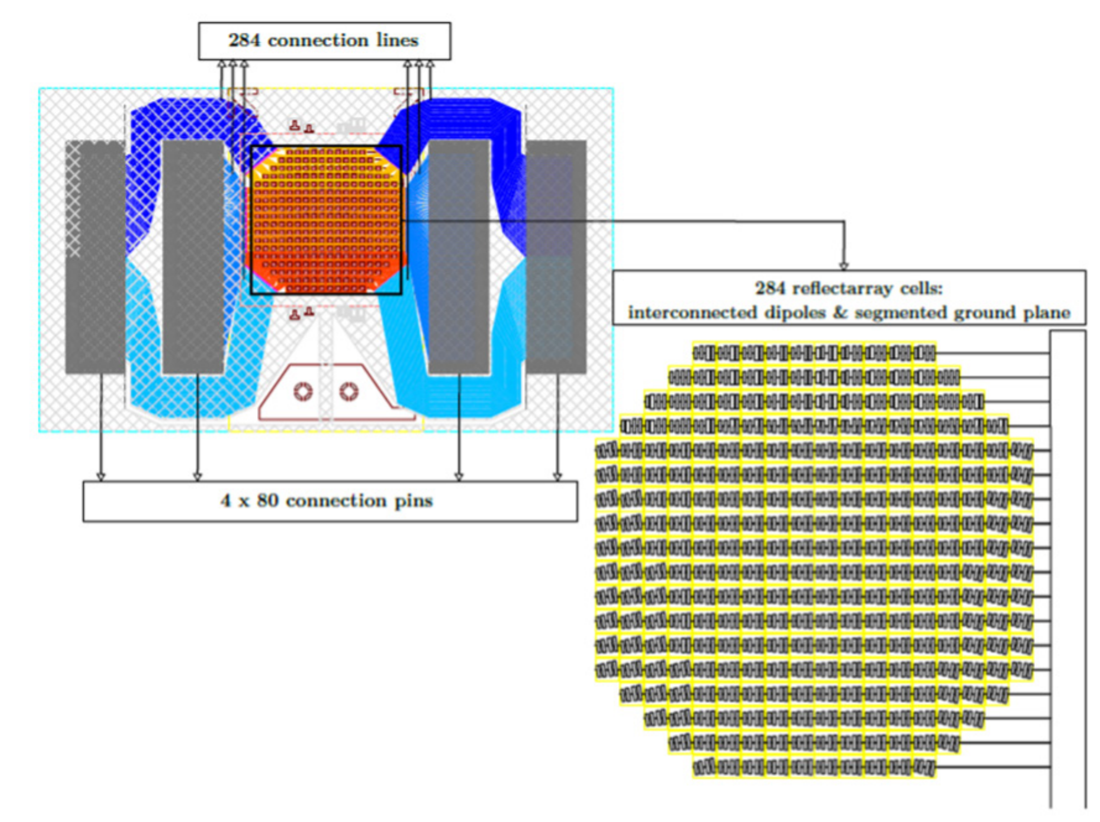
As future systems are looking into higher frequency bands, beamforming becomes a major issue to guarantee good signal quality at the receiver. Accordingly, important future research topics are related to beamforming in general, channel estimation of sparse directional channels, and beamforming algorithm design to maximize the performance of systems that depend on high antenna gains. The RISs will help by providing the possibility to modify the propagation environment, in order to provide good signal quality, also in NLOS situations, in combination with application of appropriate ML techniques.

Reconfigurable Radio Technologies for D-Band

From observing the rising interest in Artificial Intelligence, it is also anticipated that radio technologies will be impacted by this trend at the physical layer in future. This is motivated by the idea that link level information may improve or enhance AI predictions on reliability, outage and performance of wireless communication networks further. For this reason, cognitive functions and reconfiguration possibilities become more and more important, which have been neglected at THz frequencies so far.

Looking at the radio technologies at D-band, The ARIADNE WP3 distinguished between cell level and site level technologies, affecting the radio propagation and the base stations respectively. The ARIADNE project aims to combine those two areas of research by new comprehensive concepts, which involves a multidisciplinary approach across all its activites.

Addressing the cell level, the development of metasurfaces for THz frequencies beyond 100 GHz is an open research field so far and the physical layer implementation is in its childhood. ARIADNE has started to classify and screen candidates that are attractive from the functional and fabrication point of view. Prototypes for planar and corrugated structures were studied with focus on their frequency selective properties. The frequency selective aspect aligns with research on multi-band / broadband radio technologies covering multiple chanels from 130 – 175 GHz.



A third element of the ARIADNE toolbox are high gain and beam-steering antennas, which enable the alignment and switching to installed metasurfaces of a radio cell. A very attractive candidate to achieve the beamswitching function is application of refelectarrays. ARIADNE has recently investigated the first LC-based antenna prototype with 286 array elements at W-band. The scaling of liquid-crystal (LC) dielectrics in frequency for applications at D-band is crucial for this approach and dedicated measurement setups for material characterization beyond 100 GHz have been developed recently for that reason.

Project Consortium

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