Novel Scenarios and Applications **Beyond 2020**

Outline

- Scope
- Methodology
- Scenarios
- Test Cases
- Potential Solutions

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Scope

- Presentation of **novel telecommunication scenarios**.

- We move from typical telecommunications to more advanced forms that will
  - Exploit societal aspects,
  - Solve more complex problems.

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Methodology (1/3)

- Scenario definition:
  - "An internally consistent view of what the future might turn out to be",
  - "A tool [for] ordering one's perception about alternative future environments in which one's decisions might be played out right",
  - "A disciplined method for imagining possible futures".

- Scenarios are:
  - Flexible,
  - Generic.

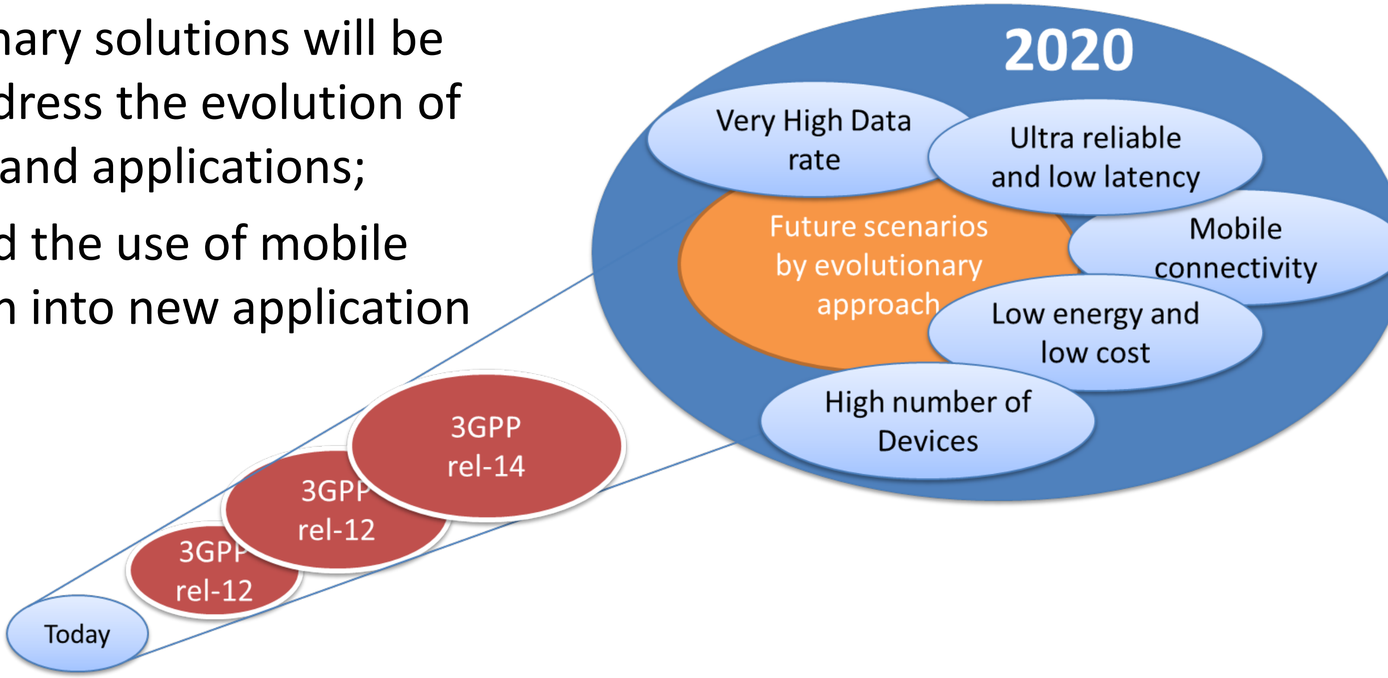
Methodology (2/3)

- Test Case definition:
  - Description that contains specific features,
  - It furthers clarifies a scenario,

- Contains:
  - a mathematical formulation, or simulation models numeric
  - assumptions, constraints, requirements etc.

Methodology (3/3)

- It is hard to foresee today which **business case** will be successful in ten years from now.
  - features will be based on natural evolution of today's networks.
  - New revolutionary solutions will be required to address the evolution of mobile broadband applications;
  - it might expand the use of mobile communication into new application fields.



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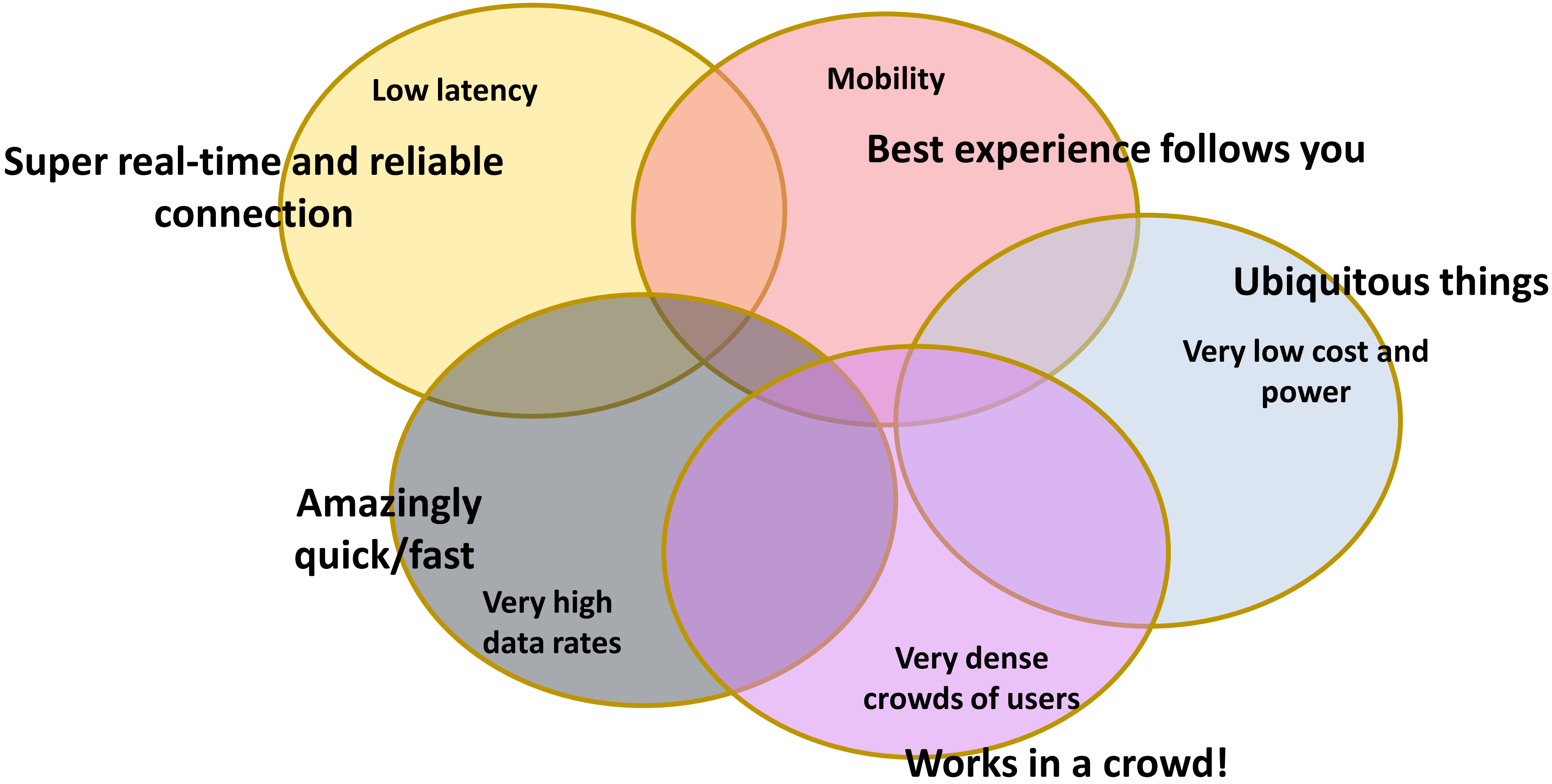
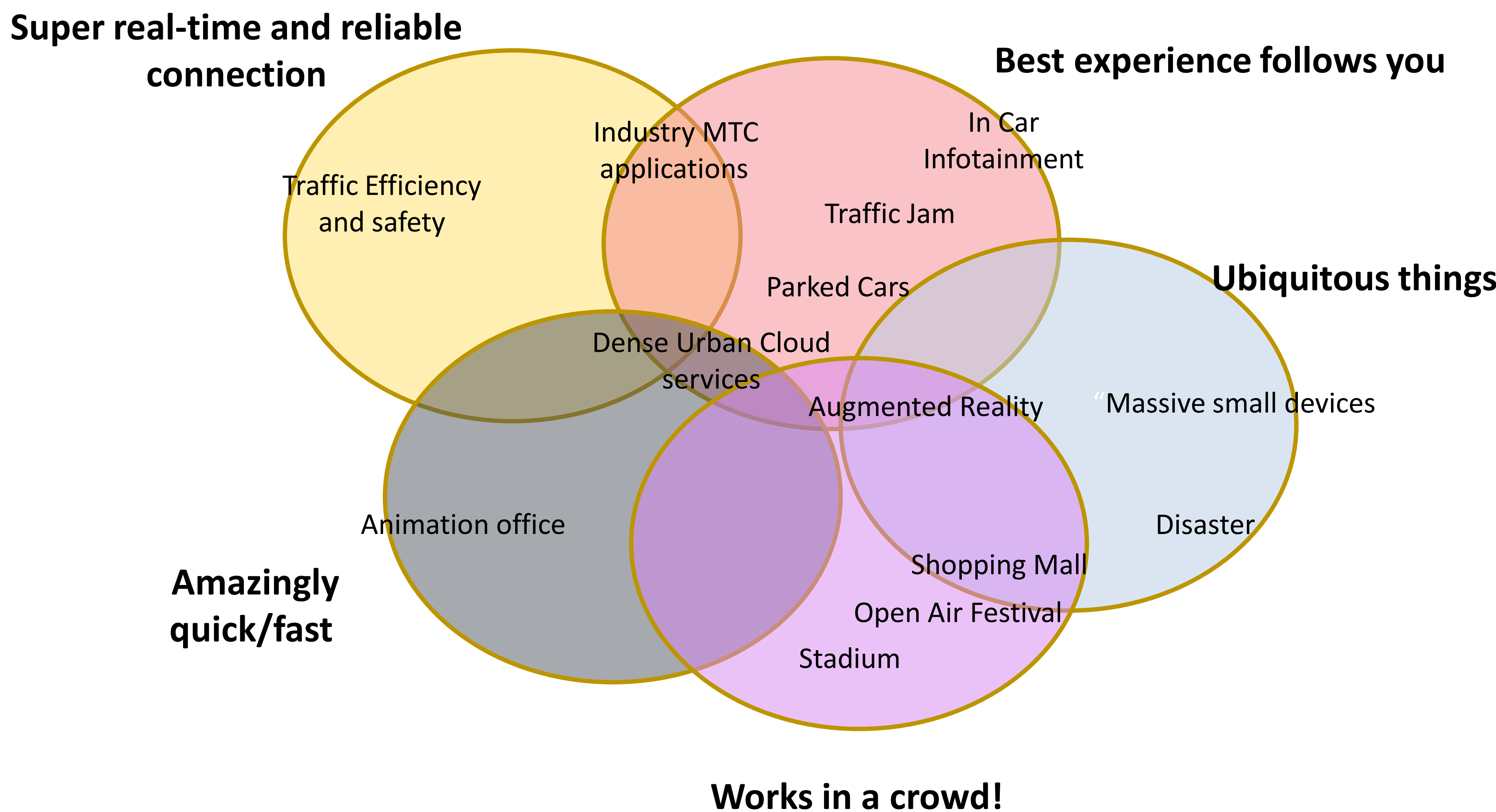
Considered Test Cases

#	TC Name	Short Description
1	Animation office	Ultra high speed communication among users with limited mobility.
2	Dense urban cloud services	High speed communication among users with unpredictable mobility patterns.
3	Shopping mall	Communication in highly crowded places with available infrastructure and user mobility
4	Stadium	Communication in highly crowded places without infrastructure and limited user mobility
5	Augmented reality	Communication exploiting information from sensors so as to enhance user experience
6	Traffic jam	Communication in infrastructure-less places with low mobility
7	Parked cars	Use of parked cars as relays so as to increase capacity
8	In-car infotainment	Use of car’s resources to access communication services, in places with limited coverage.
9	Open air festival	Access communication services in places with limited coverage and infrastructure; new services might be available.
10	Disaster	Communication in case of a disaster, where limited or no infrastructure exists.
11	“Massive small devices”	Large-scale sensor applications for monitoring with limited mobility
12	Traffic efficiency and safety	Communication among cars for efficiency or safety reasons.
13	Industrial/Agricultural applications	Large-scale device deployment for monitoring, and managing industrial applications

Scenarios Beyond 2020



Scenarios Beyond 2020



Low Latency

- Slogan:
  - "Super real-time and reliable connection"
- Purpose:
  - Empowering (new) industry with real-time & reliable connection.
- Technical Description:
  - **Delay-constrained** and **reliable communication** enabling critical machine-type applications
    - Strict E2E latency constraint
    - Very high reliability
    - Machine-type communication
  - with **large number** of connecting devices.

Mobility

- Slogan:
  - "Your best experience follows you!"
- Purpose:
  - Having the same user experience (as at home or office) on the move (no matter where you are and how you are moving),
  - Examples:
    - Even if you are with your car in the desert,
    - Even if you are in a traffic jam on a highway in the middle of nowhere.
- Technical description:
  - Ability to deploy network even in unplanned places and with unplanned devices,
  - Ability to build the network on the need, as fast and dynamically as possible,
  - Ability to provide robust connectivity for mobile devices/terminals,
  - Ability to coordinate moving devices in order to provide new services (such as traffic safety).

Very low cost and power

- Slogan:
  - “Ubiquitous things”.
- Purpose:
  - Increase environment conception for improved user experience,
  - Building network’s intelligence.
- Technical Description:
  - Communication among machines/sensors/devices-"things"
    - communicating things of low cost,
    - with low power consumption requirement,
    - very high number of communicating things,
    - low communication overhead a major target.

Very dense crowds of users

- Slogan:
  - "Good service in very crowded places like at home"
- Purpose:
  - Be (seamlessly) connected even in the most crowded places,
  - Stay connected, always on,
  - Take the Internet with you,
  - Fast all around demand-driven connection/service.
- Technical description
  - High data rates in very crowded scenarios, areas with very high user density,
    - Very high capacity per area,
    - Very high density of users (more than $2/m^2$ in general),
    - Generally low velocity and moderate latency,
  - Predictable quality of service,
  - More energy efficient,
  - Cost effective solutions.

Very high data rates

- Slogan:
  - Amazingly fast
- Purpose:
  - Instantaneous connectivity; flash behavior
  - Get all you need, when you need, where you need
  - Smart pipes at your hand
  - Great experience
  - Professional applications no longer hindered by speed
- Technical aspects:
  - High data-rates (at physical layer and experienced)
  - New spectrum bands
  - Beyond high data-rates
  - Flexible high data-rates

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Animation Office

- A top-modern office space is opened in a refurbished XIX-th century building, classified as cultural heritage. The building is rented by a computer animation company, specialized on 3D animation.
- The raw data-rate of a 3D (stereo) can exceed 25 GBytes/s, but due to the modeling techniques used in the animation process, the raw data needed to describe a scene is 1 Gbps, from which the 3D image can be rendered.
- Stakeholders
  - The real estate owner
  - The deployment and operation may be done in cooperation
  - Equipment manufacturers
- Requirements:
  - Low user mobility
  - 10 m^2 per person
  - 1 Gbps

Dense urban cloud services

- There is a broad variety of different services available for the end user, similar to Google drive, Microsoft SkyDrive video service, cloud back-up service, 3D and HD video down/uploading and real-time sharing / streaming, enhanced video conferencing, desktop cloud, gaming, advanced social networking services, etc
- People, in urban environments tend to follow unpredictable moving patterns.
- Stakeholders:
  - The network operator owning the core network and potentially the data centers.
  - The cloud service providers.
- Requirements:
  - transfer files of 10 MB within several ms
  - increased active users' density (reaching 1000/km^2).

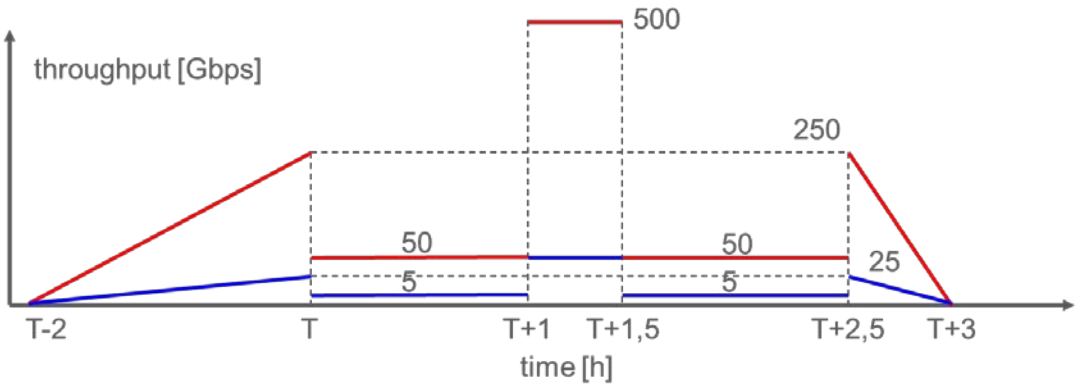
Shopping Mall

- In the shopping mall the customers will be navigated via their devices (indoor navigation) to the shops of their preference (if selected before).
- In addition they will get further personalized information dependent on their location before or inside the shops, may be on their own devices or after interaction between device and shop infrastructure via audio/visual screens (based on own App provided by the shopping center).
- Stakeholders:
  - The mall owner,
  - The operators.
- Requirements:
  - Very high density of users,
  - Uncoordinated users,
  - Very high capacity/m^2 ,
  - Assured mobility (low speed).

Stadium (1/2)

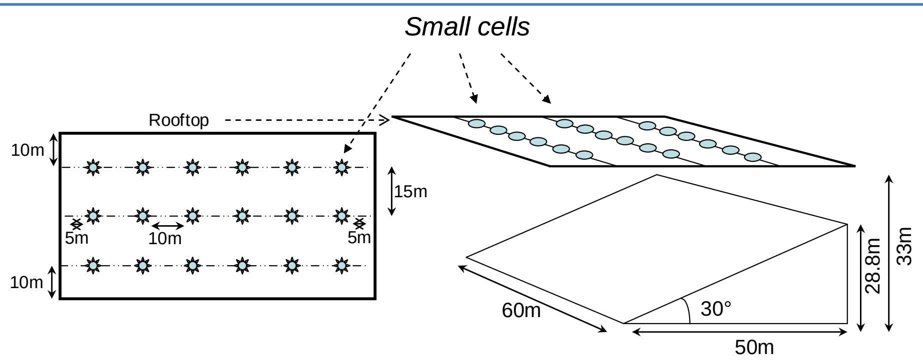
- Event in a stadium with a lot of people – the people are trying to consume demanding services.
- Requirements
  - Average throughput in the stadium/sport event compared to previous situation (100Mbps),
  - Consider presence of many tenths of thousands people (and hence devices) in the same place at the same time, most of them requiring data access,
  - Low mobility,
  - Available infrastructure.

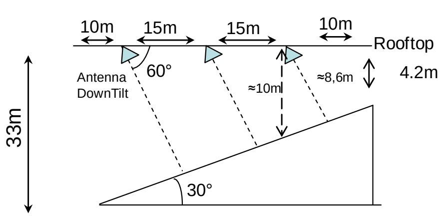
Stadium (2/2)



Throughput model – over time

Stadium model





Augmented reality (1/2)

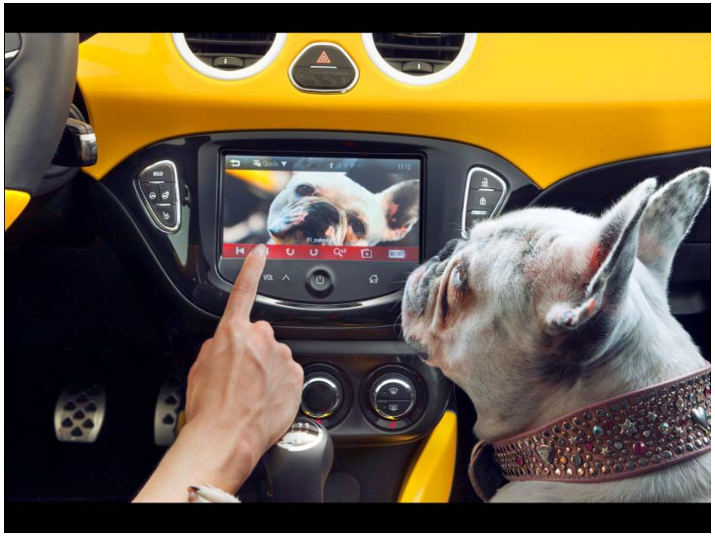
- Devices will provide information about the surrounding of the users. They could be sensors measuring a certain phenomenon, or tags providing information about the presence of certain objects of interest.
- The real world and the virtual world will become increasingly connected, as the human users will be provided with augmented reality services.
- For a full experience of the augmented reality, information could be fetched also from high data-rate sources, such as wireless connected cameras, data-bases, servers, etc.

Augmented reality (2/2)

- Stakeholders:
  - The equipment manufacturers that will provide the equipment (device and sensors),
  - Software development companies,
  - Any company which wants to advertise its services and provide services through augmented reality.
- Requirements:
  - Up to 1000 wireless nodes/km^2 supported,
  - 10-100Mbps data rates,
  - 10 high-end sensors per device up to x100 connected devices in total.

Traffic jam (1/2)

- Addresses the communication needs of humans and vehicles when they are unexpectedly stuck in a traffic jam, in an area where the traffic volume is typically much lower than the amount of data generated during the traffic jam.
- The main challenge in this scenario is related to the fact that video services have to be delivered in an efficient manner so that network operators can cope with the transmission of many medium to high quality (> 1 Mbps) video services at affordable cost.

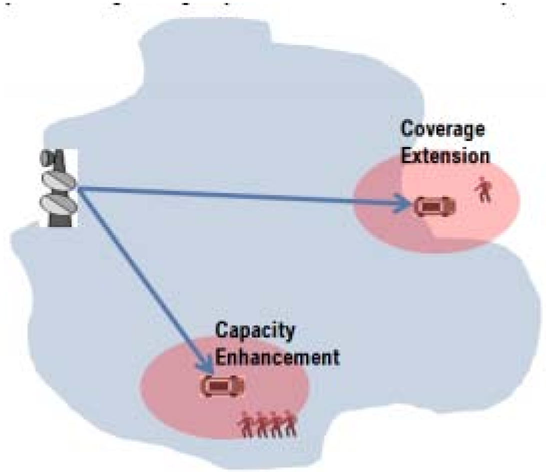


Traffic jam (2/2)

- Traffic jams are prone to occur in rural areas or in the access roads to major urban centers.
  - In the former, the provision of high data rate services is quite challenging due to the sparse network infrastructure deployed by mobile network operators,
  - whereas in the latter, the sudden increase in the demand for radio resources can saturate the existent network infrastructure and compromise the provision of services to the users in the surrounding area.
- Stakeholders
  - Network operators own the infrastructure and are in charge of providing wireless connectivity
  - Vehicle manufacturers can become stakeholders by offering video-on demand services to the end-users
- Requirements:
  - Limited network infrastructure,
  - Users considered with a mobility from 0-30 km/h,
  - Movement of users and communication patterns probably highly predictable according to the traffic jam,
  - Seamless consumption of video services regardless of the number of users,
  - Capacity up to 20 Gbps per km2 for users in the traffic jam. This value has been obtained by considering a maximum of ten lanes in the road (five in each direction) and the consumption of four different HD video services at 4 Mbps per vehicle.

Parked cars (1/2)

- In 2020, the wireless device with on-board high gain antennas will be installed in many vehicles.
- The vehicles will provide a dynamic network of data hotspots (relays) that can be flexibly activated and deactivated depending on traffic, service, bandwidth and coverage demands. In other words, they can provide the functionality as a **dynamic and nomadic hotspot**.
- That allows for a strong and reliable backhaul/relay link even in areas where the mobile received signal level is quite weak for conventional terminals.

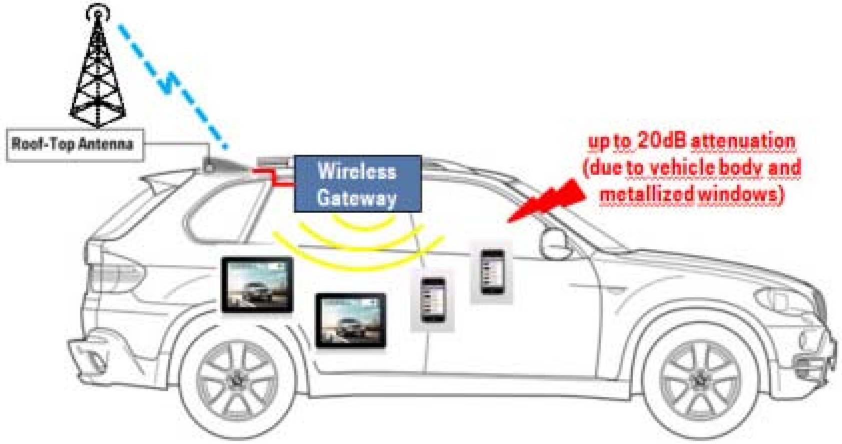


Parked cars (2/2)

- Stakeholders
  - The vehicle manufacturers that install the hotspot device in the vehicle,
  - Network operators who controls the communication and radio resource of vehicle hotspot,
  - Other car related company like rental car company or car sharing service company.
- Requirements
  - Data Traffic: More than 80% of users are supposed to higher than 20 Mbps in downlink even at low signal level conditions at cell edge of macro-cells
  - Power consumption: decrease with factor 5 compared to the existing system. In best case, vehicle may be connected to electric charging station - total power consumption should be lower than 2W for vehicular cells.
  - Positioning: Relative positioning accuracy 1-5 m.
  - Mobility: User mobility from stationary to low mobility (10 km/h) and vehicular cells are considered to be stationary
  - Node density and distribution: up to 10 users served per vehicle cell
  - Latency
    - Standard internet access latencies for non-real time traffic
    - Below 10 ms with high probability for real-time traffic.
  - Range: Vehicular cells may have a range of up to 300 m.

In-car infotainment (1/2)

- In-vehicle users experience nowadays a limited QoS due to:
  - the lack of mobility management,
  - insufficient antenna capabilities
  - penetration loss of the vehicle shell (especially for cars, trains, and buses with metalized windows).
  - rural area and mountain area where the wireless infrastructure is sparsely populated and the path loss becomes large.
- The mobility management of the in-vehicle users can be transferred to the mobility management of the “moving cell”, and so realizes significantly reducing the signalling overhead and improving the handover performance.
- Stakeholders
  - The vehicle manufacturers that install the hotspot device in the vehicle,
  - Operator(s).



In-car infotainment (2/2)

- Requirements
  - Data Traffic: More than 80% of users are supposed to have higher than 10 Mbps in downlink even at low signal level conditions at cell edge of macro-cells and at high mobility condition up to 250 km/h
  - Power consumption: Total power consumption of in-vehicle cell should be lower than 2W.
  - Spectrum: Generally with existing spectrum in cellular/wifi; one spectrum within Europe would be preferable preferable frequencies for in-vehicle cells should lie between 2 GHz and 5 GHz
  - Mobility: Users are considered to be stationary, whereas in-vehicular cells are considered from stationary to 350 km/h.
  - Node density and user distribution:
    - Up to 8 user devices to active in parallel inside of cars
    - Up to 50 user devices to active in parallel inside of buses
    - Up to 300 user devices to active in parallel inside of trains

Open air festival (1/3)

- Requirement of this amounts to 80 Gbits/sec/km^2 of generated data.
  - On an area of less than 1 km^2 is visited by 100,000 visitors under 4 days (and by a small amount of people are present there the rest of the year).
  - During a concert, in average there are 4 people per m^2 at each stage.
  - Experience sharing.
- Trash bins, portable toilets, and vending machines,
- The security is ensured by good and reliable communication between headquarters, guards, medics, surveillance cameras, and a wide range of sensors. The signals from the sensors is expected to reach the headquarters within 1 second. 99% of the sensors and safety devices are expected to have service coverage

Open air festival (2/3)

- Stakeholders
  - Network operators,
  - Festival organizer,
  - Security, cleaning services, etc.
  - **New service providers**

Open air festival (3/3)

- Requirements:
  - Provide capacity of 80 Gbps/km^2
  - Provide access to up to 300,000 devices per km^2, out of which up to 50,000 are smart phones
  - Low installation and operation cost: at most 10-20€ revenue per person, significantly lower per devices, sensors, actuators.
  - Be scalable, reliable to changes of topography of the network, easy to rollout, configure and maintain.
  - Enable highly connected local area access (to minimize energy consumption; share spectrum resources efficiently; and boost the usage of various local services)

Disaster (1/2)

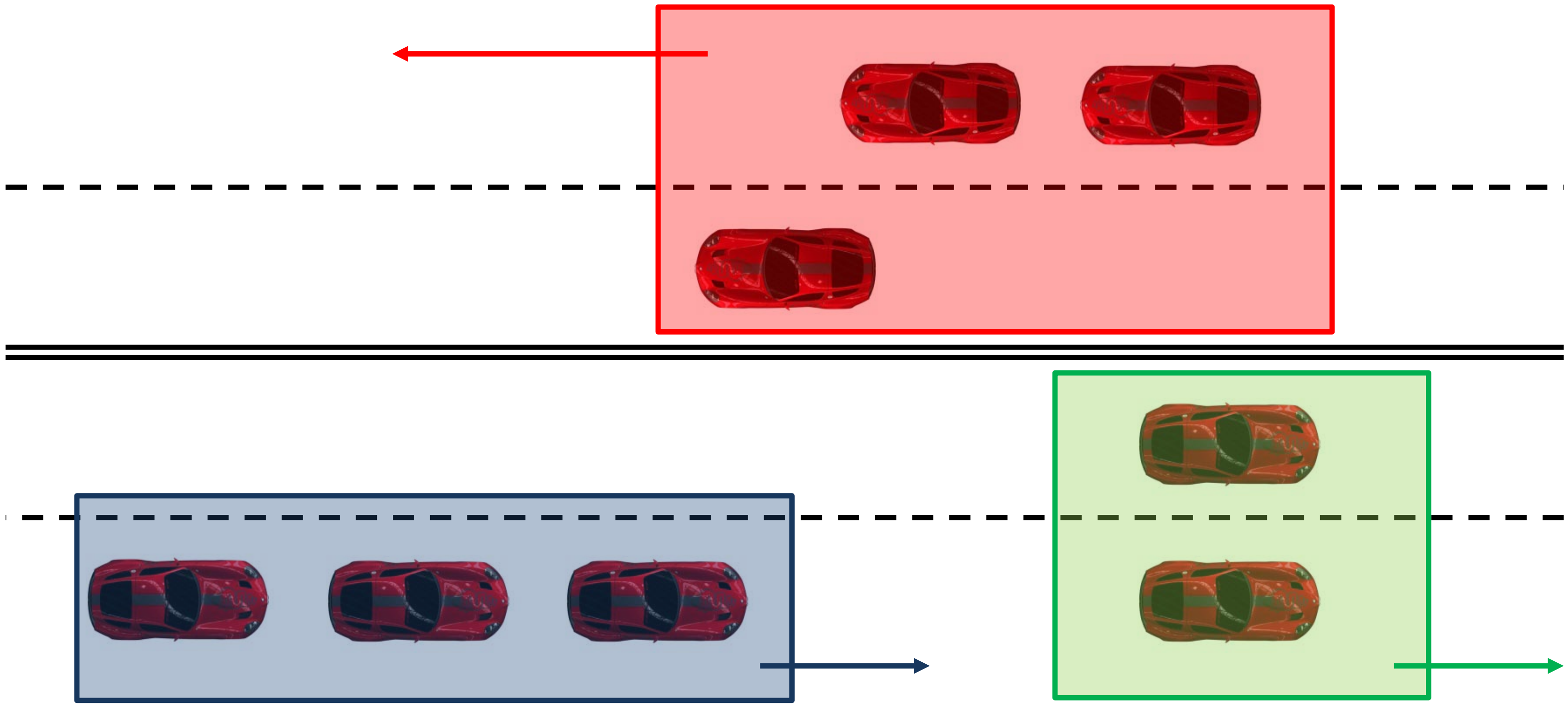
- You are in a place where no infrastructure exists (anymore) either because there has been a natural disaster or because this is an inhabited area.
- Communications are needed instantaneously on demand using regular devices.
- When such a demand is requested, devices are switched into a "recovery mode". This demand can either be requested by the network or the end-user.

Disaster (2/2)

- Stakeholders
  - the operator
  - the service provider
    - Fire department
    - Public Healthcare
    - State
- Requirements
  - In order to satisfy the user, the operator and the service provider should together provide:
  - Guaranteed service.
  - Should be working on any regular device
  - Up to 10 Mbps (uplink and downlink)

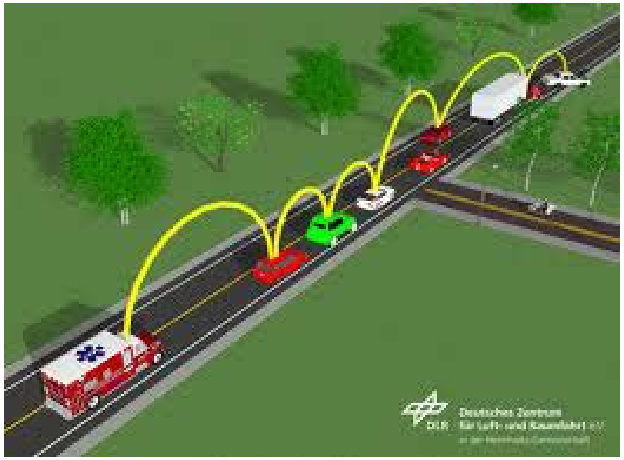
LTE already does that but under different constraints

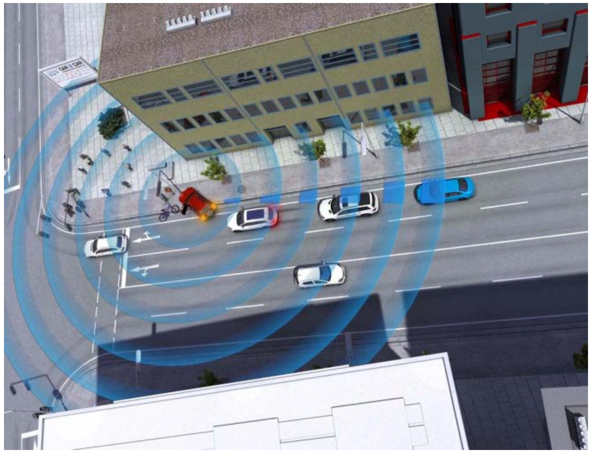
Traffic efficiency and safety (1/4)

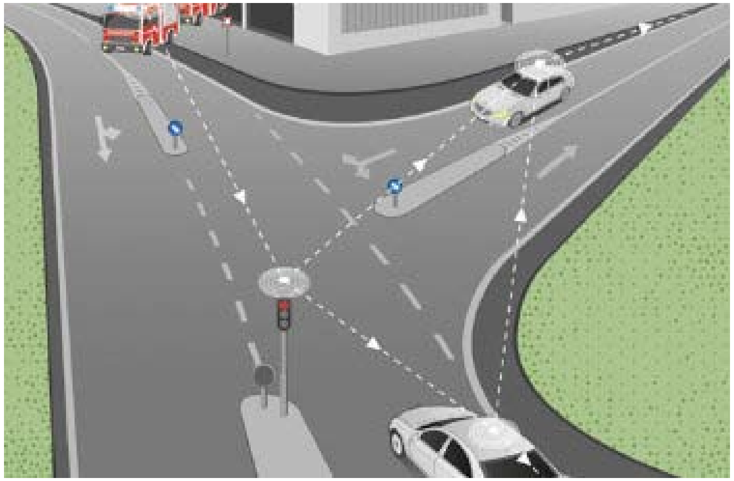


If we coordinate traffic we have significant gains in the cars' speed, routes calculation, etc.

Traffic efficiency and safety (2/4)







If we coordinate traffic we have safety gains.

Traffic efficiency and safety (3/4)

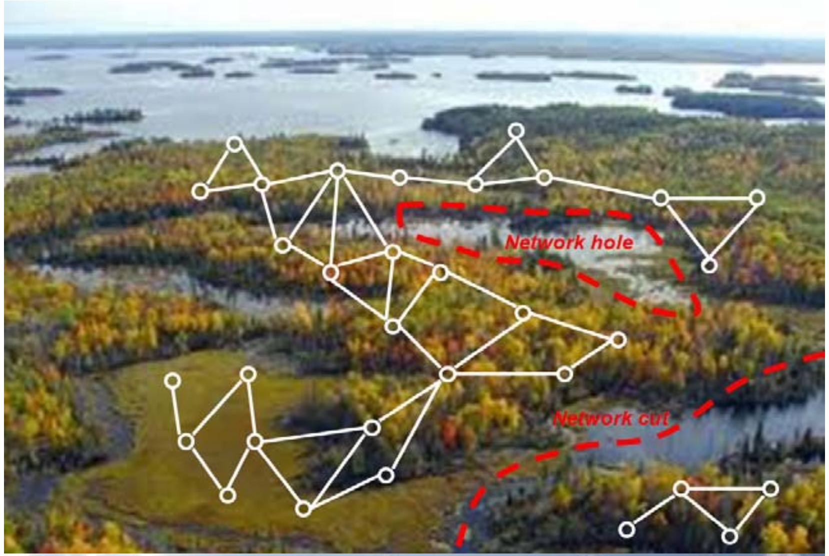
- Information exchange among vehicles enables the provision of safety hints to the driver or warnings about the road status.
- The vehicle could intercommunicate with other vehicles and actively intervene in order to avoid accidents (e.g., emergency brakes etc) based on the notification for the presence of another vehicle for the avoidance of an accident.
- Provision of safety services to the drivers is related to the notifications regarding road hazards (slippery area, an accident that is blocking part of the road).
- Efficiency is related to coordination of the cars' speed, routes, etc.

- Stakeholders
  - Network operators own the infrastructure and are in charge of providing wireless connectivity
  - Vehicle manufacturers
  - Road provider/operator

Traffic efficiency and safety (4/4)

- Data traffic
  - Periodic broadcast traffic consisting of at least 1600 payload bytes (for transmission of information related to 10 detected objects resulting from local environment perception and the information related to the actual vehicle) with repetition rate of at least 5-10 Hz. The traffic generated by each vehicle has to be delivered to all the neighboring vehicles within the specified range.
  - Event-driven broadcast traffic consisting of at least 1600 payload bytes with repetition rate of at least 5-10 Hz (for transmission of information related to 10 detected objects resulting from local environment perception and the information related to the actual vehicle)
- Mobility
  - Urban: maximum absolute velocity of 60 km/h and 120 km/h relative velocity between vehicles.
  - Rural: maximum absolute velocity of 120 km/h and 240 km/h relative velocity between vehicles.
  - Highway: maximum absolute velocity of 250 km/h and 500 km/h relative velocity between vehicles.
- Latency:
  - 10 ms maximum network end-to-end delay (including device detection, connection setup and radio transmission) with transmission reliability of 99.999% should be guaranteed to deliver the drive safety service.

Industrial/Agricultural applications (1/3)



Industrial/Agricultural applications (2/3)

- Increasing demand on wireless connectivity for fast and flexible interventions.
- wireless networks can be used for the reliable transmission of real-time information used to control industrial facilities like systems for production of goods or for distribution of resources
- These kinds of systems may require an immediate response to alter system conditions that may occur at a remote distance from the industrial site controlling the process.
- Stakeholders
  - Network operators
  - Area/building/structure owner.
  - Machinery / vehicle provider, for instance a company renting harvesting equipment to farmers
  - Hardware provider.
  - Software Development Company for the integration of the solution.
  - Service provider for the data analysis in case the analysis is not performed
  - locally.

Industrial/Agricultural applications (3/3)

- Requirements:
  - ultra low-cost of terminals
  - ultra low power dissipation of terminals (must live from a battery for as long as the lifetime of the building / structure / area to monitor – potentially several decades) device density from 10 per km^2 (e.g. agricultural application) to 5,000 per km2 (for building / structure monitoring)
  - duty cycle one day typical payload 20 bytes
  - in some cases, it may be sufficient if a subset of sensors delivers information to the Internet (as some redundancy in the placement of the sensors is foreseen, such as in the example of the agricultural application).
  - In other cases, however, it will be essential that each sensor has connectivity to the Internet

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Device to Device Com.

- What it is D2D communication?
  - Device-to-device (D2D) communications commonly refer to the technologies that enable ***devices to communicate directly without an infrastructure*** of access points or base stations, and the involvement of wireless operators.

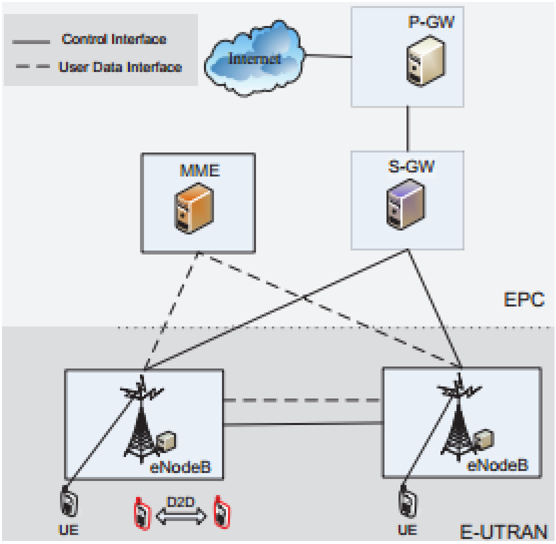
- Device
  - refers to the user who uses cell phones or other devices in Human-to-Human (H2H) communications as well as "machine" in Machine-to-Machine (M2M) communications without the involvement of human activities

Device to Device Com.

- Until now it hadn't attracted the interest of the operators, because:
  - Realization of WiFi & bluetooth
    - Requires manual pairing of the devices,
    - Low distance,
    - Unable to meet user requirements, since interference is uncontrolable,
    - Cannot provide QoS,
    - the wireless operators cannot make profits using traditional D2D technologies since they work independently without the involvement of the operators

Device to Device Com.

- Why use D2D communication?
  - of enhancing network throughput,
  - saving the power of user equipment
  - increasing an instantaneous data rate
- Why NOT use D2D communication?
  - probability of local communication might be low
  - propagation channel between devices is ”worse” than propagation channel between a BS and devices
  - interference to and from in-band cellular mode users



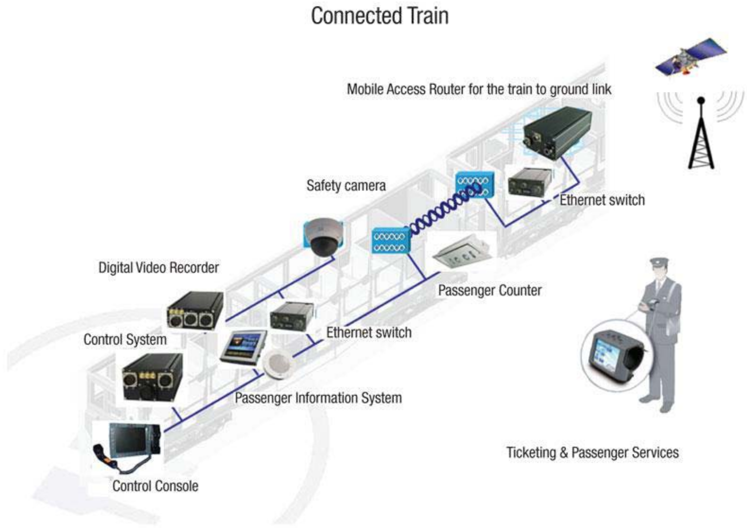
Machine to Machine Com.

- What is M2M communication?
  - Data flow of data between machines and machines.
  - Regardless of the type of machine or data, information usually flows in the same general way -- from a machine over a network, and then through a gateway to a system where it can be reviewed and acted on.

- Within that basic framework, there are many different choices to make such as **how the machine is connected**, what **type of communication is used**, and **how the data is used**.

Machine to Machine Com.

- When it comes to the finer points of machine to machine communication, every deployment is unique. However, there are four basic stages that are common to just about every M2M application. Those components are:
  - Collection of data
  - Transmission of selected data through a communication network
  - Assessment of the data
  - Response to the available information



Ultra Dense Networks

- Ultra-dense Networks will be the main driver to address
  - the traffic demands of beyond 2020 and where the aims are to increase capacity (capacity efficiency),
  - increase energy efficiency of radio links,
  - and enable better exploitation of under-utilised spectrum

- Ultra-dense deployments raise many new challenges e.g. related to mobility and backhauling.

- Ultra Dense networks have aspects related to:
  - Cost,
  - Energy,
  - spectral efficiency.

Other Solutions?

- Something else maybe ?????
  - Other frequencies?
  - Spectrum sharing?

“Questions are guaranteed in life;
answers aren't”