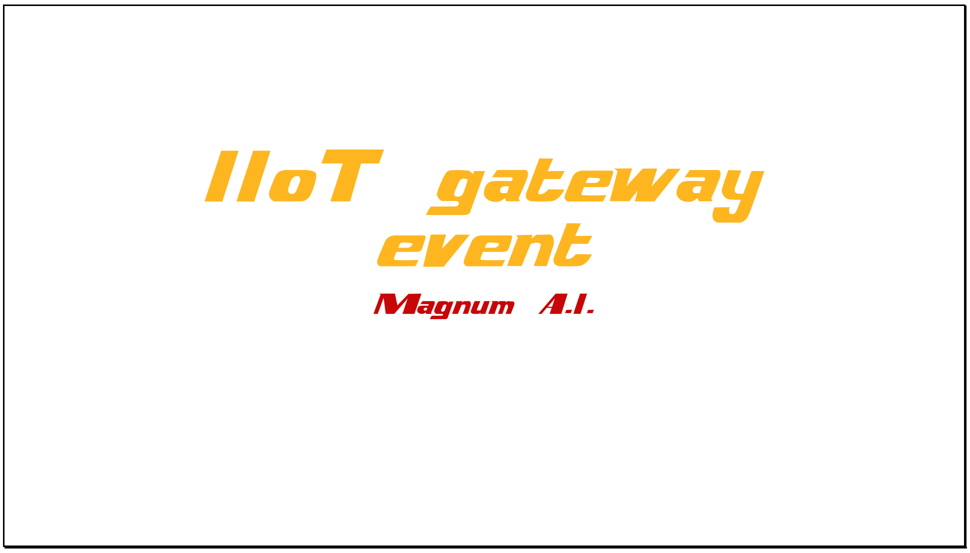
Slide 1



AI	Artificial intelligence
ASIC	Application specific integrated circuit
CNN	Convolutinal neural network
DNN	Deep neural network
DRAM	Dynamic random access memory
FPGA	Field programmable array
GPGPU	General purpose graphical processor unit
IIoT	Industrila internet of things
I/O	Input/output
ITRI	Industrial Taiwanese research institute
Yolo	You only look once
TTI	Transmission time interval

Slide 2

Introductory clips
1, 2, 3 and 4

A typical no walls open factory floor.

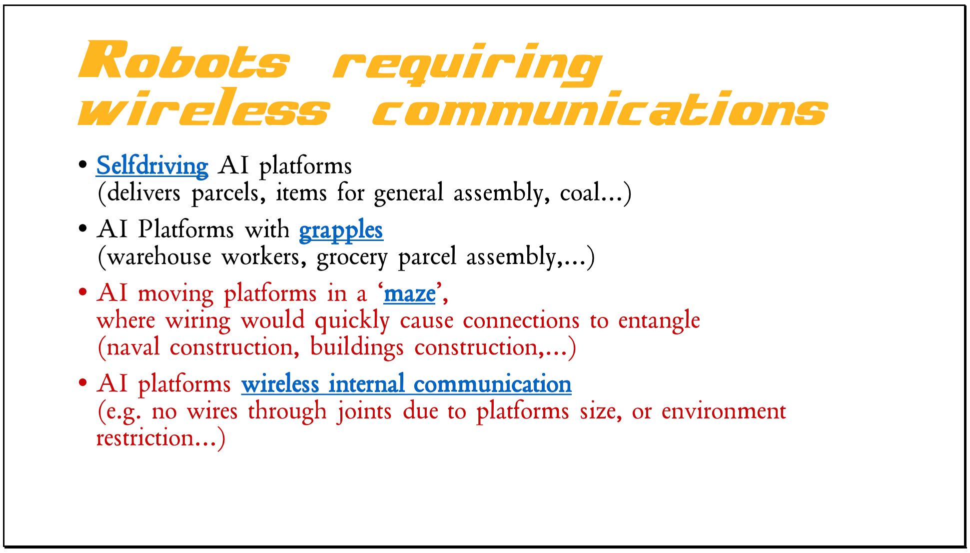
Since 2012., when Deep neural network running on video games card, using computer vision, was able to recognise objects on image better than human can recognise objects on image, the advance of Artificial intelligence became unstoppable.

New type of robots using DNNs are becoming available, increasing human productivity.

- Selfdriving AI platforms:
  Reusing algorithms derived for selfdriving cars, it’s possible to increase the throughput of items handled in:
    - Warehouses, where parcels can be delivered from point to point
    - Assembly lines, when e.g. building cars
    - Mines, to transport ore
    - …
- AI platforms with grapples:
  Computer vision enables robots to recognise objects, but also understand the pose of objects, easing object manipulation with robotic arms.
    - Warehouse workers (as researched by Boston dynamics)
    - Grocery parcel assembly (as implemented by Ocado)
    - …

(Continues next page.)

Slide 3



- AI platforms moving in a 'maze'
  There are robots that can be wired, but without using wireless connection the number of deployed robots in the 'maze' is greatly reduced. E.g., in:
  - Shipyards, robots doing welding can use wired connections, but it's easy to see how impractical that is. Especially for robots operating inside the ship.
  - Building construction sites, where the environment is changing and wired connections would have to be moved all the time from floor to floor. Wireless connection makes the site tidy and safe.
  - …
- Robots with internal wireless connections,
  would operate in environments where internal wiring of robot extensions is difficult. E.g.:
  - Robots helping to save earthquake victims cannot have wires protruding outside of the metal robot body.
  - Small robots cannot physically accommodate wires
  - Robots operating in toxic, or challenging atmosphere cannot have wires exposed
  - Robots moving joints at high speed will cause wire fatigue
  - …

Note: cases 3 and 4 are not part of the first IIoT gateway event, as not of practical interest for now (2018.).

Slide 4

Architecture

- No walls open factory floor
- Small cell private network
- AI moving platform(s)
- AI on the Edge
  - ASIC, GPGPU and/or FPGA based DNN accelerators
- IoT sensors

There has to be real time communication between AI moving platforms and AI backend. Typical delays in both, AI and Small cell network must be of 10ms order delay.

DNN accelerators will be running Yolo and PoseCNN.

Small cell private network will be running **WiFi**, 4G (CBRS), 5G and other.

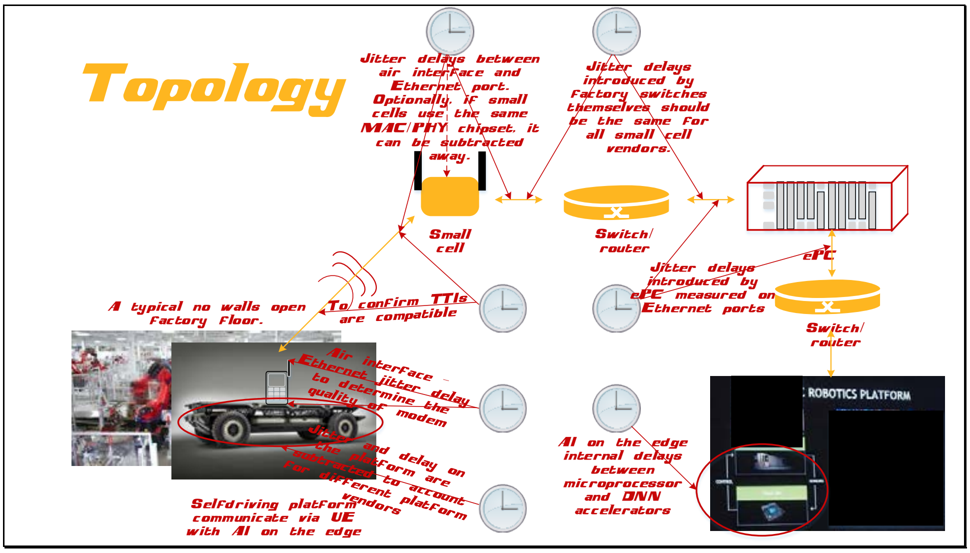
The (I)IoT gateway event should take place in a realistic environment, e.g. on the factory floor, with no fixed wall, and challenging radio conditions (metallic roof and walls, with plenty of fixed and moving structures throughout the floor.)
The typical size of factory floor would be 50m x 100m x 10m.

Small cell private network shall incorporate proper redundancy, SON self-healing algorithms.

AI moving platforms shall each have e.g. 4x high definition cameras connected through modems to Small cell private network and further to AI on the edge. AI moving platform shall have ability to store processed video feed from the edge, so it will be able to compare the original and processed video feed.

Some AI on the edge platforms can work with a couple of milliseconds latency, but it’s expected that the entire AI application on the edge will have a couple of tens of milliseconds.
Small cell private network will also operate in tens of milliseconds latency.
It’s plausible that (I)IoT vertical system integrator shall put the effort to remove the worst bottleneck first.

Slide 5



The first objective of (I)IoT gateway event is to indicate bottlenecks and make sure **Small cell private network is not a bottleneck**.

There are already AI on the edge platforms from major AI vendors, and all these platforms include WiFi.

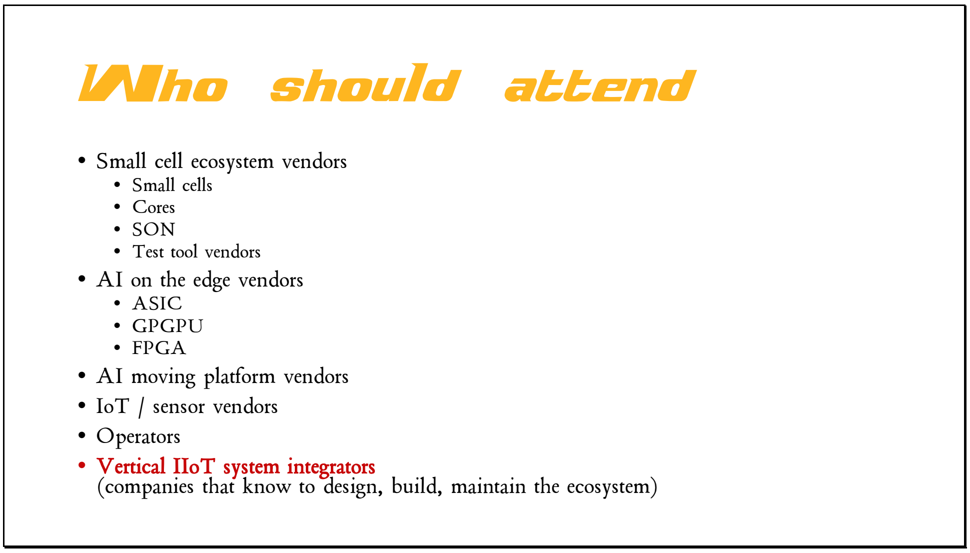
The second objective of (I)IoT gateway event is to indicate **which radio technologies** are appropriate for which use cases, especially delineating WiFi, 4G and 5G use cases. Here, it should be clear WiFi appropriate only for demo/prototyping purpose.

AI on the edge shall take two types of inputs:

- from moving AI platforms
- from fixed sensors

The third objective of (I)IoT gateway is to ensure Small cell private networks assign **correct QoS between moving AI platforms and fixed sensors**.
Note: Sensors are IoT sensors which require high bandwidth readouts (not NB-IoT).

Slide 6



Operators should participate as observers and/or spectrum holders.
AI implementaions in IIoT operates in a smaller and more challenging environments than AI in municipal environment (e.g. robotic waste collection in town). IIoT implementations are potentially more lucrative and will attract more startup capital, they will iterate in development faster, are cheaper to setup and failure rate of deadend designs will be fast. Operators should in later stage identify IIoT soutions applicable for the deployment city and nation wide. City widedeployment might require macro network reengineering by placing GPGPUs next to the base station, e.g.

Small cell test tool vendors can use the IIoT gateway event to start creating test harnesses.

Vertical IIoT system integrators are companies like Siemens or ABB which don't manufacture robots or small cells but would design factory floor, place and program robots, took the ownership of end-to-end design and face the end customer (a factory), providing support and maintenance.

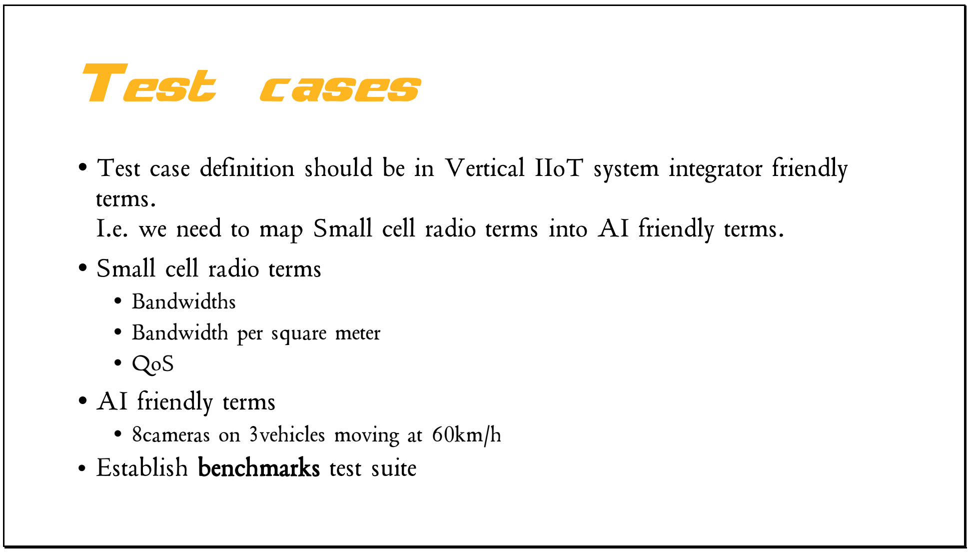
The fourth and the most important objective of the IIoT gateway event is to help **Small cell companies and vertical integrators establish contacts**.

Slide 7

Use cases

- Selfdriving AI platform (ITRI)
- Sensor network (high bandwidth) readouts (ITRI)
- TBC

Slide 8



Test cases should start from simple to more difficult scenarios:

- A single moving platform with 4x high definition cameras moving at 10km/h.
  (It's expected WiFi will be sufficient.)
- As we expect moving platforms to come into ~1m proximity to each other, we start grouping platforms (e.g. forming platoons). 2x moving platforms, then 4x moving platforms,...
  (It's expected that even with 2x moving platform, because of the bandwidth per sq. meter.)
- We introduce redundancy mechanisms, by disabling one radio head during the test and observe self-healing latency.
- Velocity of moving groups is increased in the steps of 10km/h.
  (It's expected that we have to move from 4G to 5G.)

Test cases shall be defined in both small cell radio terms and veritical integrator terms translating:

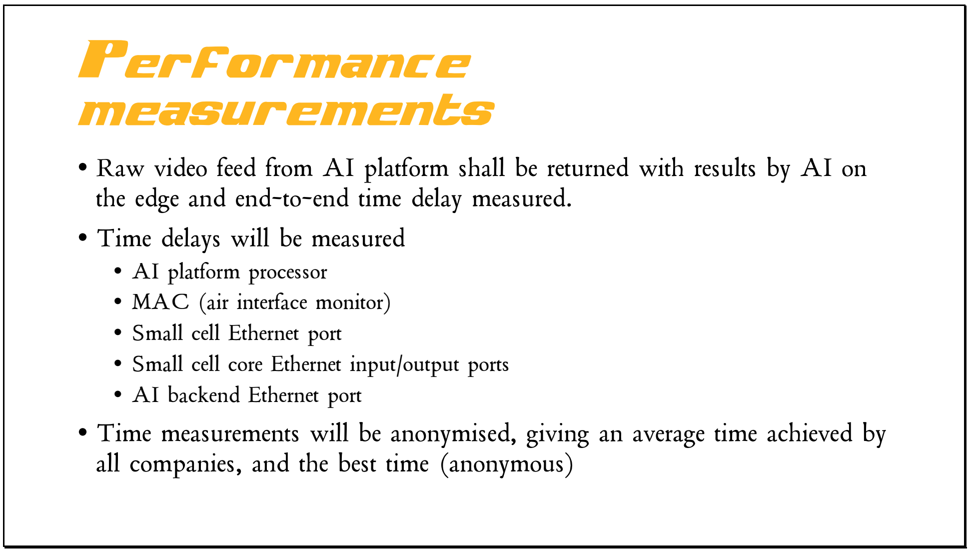
- bandwidth, bandwidth per square meter
- delay, jitter
- error rate
- outage recovery time

into:

- number of cameras per vehicle/ number of vehicles per sq meter/ velocity of vehicles supported
- emergency stop
  (e.g. radio system cannot support full operation any longer and has to reconfigure

with reduced service - selfhealing in the case of emergency. This reconfiguration has to happened within given time.)

Slide 9



Jitter and delay shall be measured at the points which will indicate bottlenecks:

- AI platform modem bottleneck identified measuring jitter delay between modem and small cell on air interface (e.g. mismatch in the best possible TTI)
- Delays jitter due to AI platform processor (e.g. too low powered microprocessor) shall be measured
- If small cell MAC scheduler not optimised, it will be discovered by jitter delay between air interface and Ethernet ports on the small cell. (Should Baseband chipset vendors provide independent measurement, it will be possible to understand delays due to small cell vendors SW or chipset BB/RF chipset)
- If core switching matrix not optimised on ePC core, it will be visible on core Ethernet ports jitter delays of appropriate video streams.
- Factory switches will introduce some jitter delays, and some typical numbers should be measured (though factory switches will be standardised through Industry 4.0 standards.)
- AI on the edge will have many internal sources of delay jitter (examples):
    - microprocessor I/O operations, putting data on PCIexpress
    - GPGPU kernel loading/offloading and moving data to local DRAM

The fifth objective of the event is to help **vertical IIoT system integrators understand small cells in friendly terms**.

The sixth objective of the event is to begin establishing **benchmarks** test suite.

Slide 10

Business case

- Robotisation favours smaller companies:
  - e.g. automating 10jobs in the workshop of 20workers increases productivity 100%.
  - legal (spectrum and safety), operational (installation), number of iterations of the system aspects are all easier to achieve
- There are already companies able to close the whole vertical integration on small cell/AI side. What's missing is the end factory floor application.
  - Everyone else should work speedily on joining this emergiing ecosystem.
- Identifying in which IIoT use cases small cells are bottlenecks will decide their commercial value

Slide 11

Objectives

1. make sure **Small cell private network is not a bottleneck.**
2. indicate **which radio technologies** are appropriate for which use cases, especially delineating WiFi, 4G and 5G use casesensure Small cell private networks assign **correct QoS between moving AI platforms and fixed sensors..**
3. ensure Small cell private networks assign **correct QoS between moving AI platforms and fixed sensors.**
4. help **Small cell companies and vertical integrators establish contacts.**
5. help **vertical IIoT system integrators understand Small cells in friendly terms**
6. establishing **benchmarks** test suite The sixth objective of the event is to begin establishing benchmarks test suite.

Slide 12

Scope

Scope of IIoT gateway event TBC