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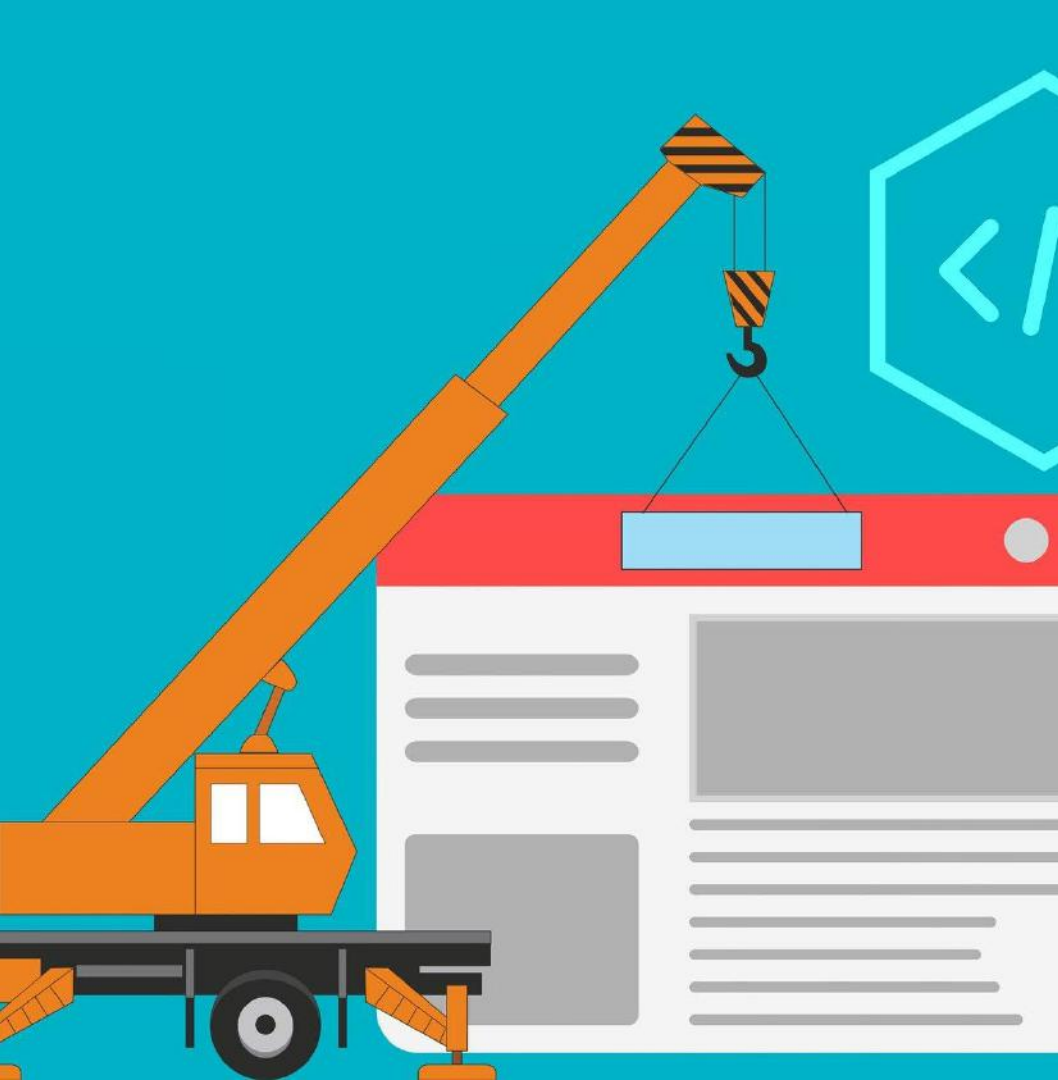
Virtual FEC11

Online, 05/05/2022

Open Call Review

TIGER

ExperimentaT**al evaluation of a new IoT board embedding
5G t**E**chnology in Fed4Fi**R**e+ (F4Fp-SME-COD210907-01)**



Part I – Experiment Description & Technical Results

EXPERIMENT DESCRIPTION

BACKGROUND & MOTIVATION

- **USP:** Generic hardware fully supported by software for building new IoT services: from ideation, to pilot & full-scale stages
- **ROADMAP:** Extend the insigh.io portfolio to support 5G-IoT technologies and apps (e.g. drones)
- **CURRENT STATUS:** First Company's MVP underway using standard COTS components
- **FED4FIRE+ VALUE:** Verify and Evaluate the basic MVP KPIs in a 5G testbed



EXPERIMENT DESCRIPTION



CURRENT LIMITATIONS

- 5G network roll-out and commercial services still at initial stage delaying practical testing
- Even if a public network is available, testing has shortcomings:
 - Unknown radio conditions
 - Unpredictable background traffic load conditions
 - Zero input for network configuration and parametrization
 - Heavy data usage

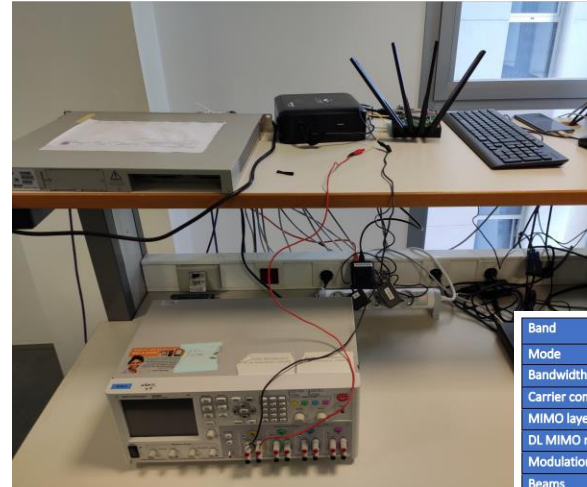
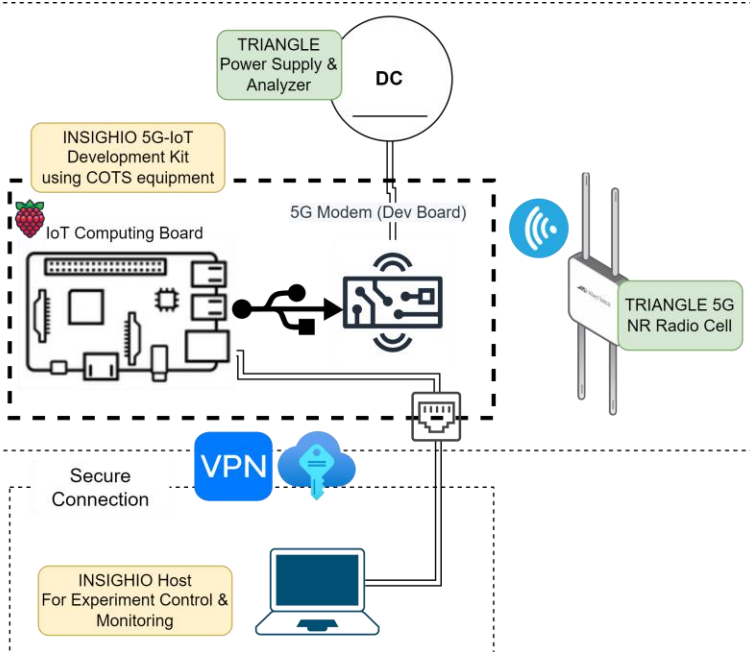
OBJECTIVES

- Validate the product prototype in TRIANGLE's 5G network testbed
- Perform a systematic MVP assessment in real-world conditions
- Identify performance upper bounds/limitations in controlled setups
- Move the prototype from lab to real-world using a private 5G cell
- Push the boundaries of 5G-IoT experimentation in F4F+

EXPERIMENT DESCRIPTION

SETUP

TRIANGLE DEPLOYMENT



5G connectivity validation
 Network performance evaluation
 Energy consumption evaluation

Band	n78
Mode	TDD
Bandwidth	40 MHz
Carrier components	1 Carrier
MIMO layers	2 layers
DL MIMO mode	2x2 Closed Loop Spatial Multiplexing
Modulation	256QAM
Beams	Single beam
LTE to NR frame shift	3 ms
Subcarrier spacing	30 kHz
Uplink/Downlink slot ratio	1/4

Band	B7
Mode	FDD
Bandwidth	20 MHz
Carrier components	1 Carrier
layers	4 layers
DL MIMO mode	4x4 Closed Loop Spatial Multiplexing
Modulation	256QAM

PROJECT RESULTS



MEASUREMENTS & LESSONS LEARNT (1/3): 5G RADIO CONNECTIVITY VALIDATION

AT Command (Scope)	Output
AT+CEREG? (Network Registration Status)	2,1,"1","12C",13
AT+COPS? (Selected Operator)	0,0,"TestNetwork Telikom PNG",13
AT+QENDC (Dual Connectivity Status)	1,1,0,1
AT+QNWINFO (Network Information)	"FDD LTE","00101","LTE BAND 7",2850 "FDD NR5G","00101","NR5G BAND 78",651648
AT+QENG="servingcell" (Primary Serving Cell Information)	"LTE","FDD",1,01,12C,318,2850,7,5,5,1,-60,-10,-29,25,15,-330,- "NR5G-NSA",1,01,3,-57,34,-11,651648,78,6,1
AT+QNWCFG="NR5G_dIMCS" (NR5G Downlink MCS and Modulation type)	"nr5g_dIMCS",1,27,3
AT+QNWCFG="NR5G_uIMCS" (NR5G Uplink MCS and Modulation type)	"nr5g_uIMCS",1,0,1
AT+QNWCFG="NR5G_PUSCH_data (Get Uplink signaling channel data)	"nr5g_pusch_data",1,1,0,1,80,14,51

- ✓ The 5G modem supports “out-of-the-box” LTE/NR dual connectivity in NSA mode
- ✓ The acquired DL PHY Mode (256QAM) agrees with the settings
- ✓ Reinvestigate UL PHY Mode (QPSK)

PROJECT RESULTS



MEASUREMENTS & LESSONS LEARNT (2/3): 5G NETWORK KPIS ASSESSMENT

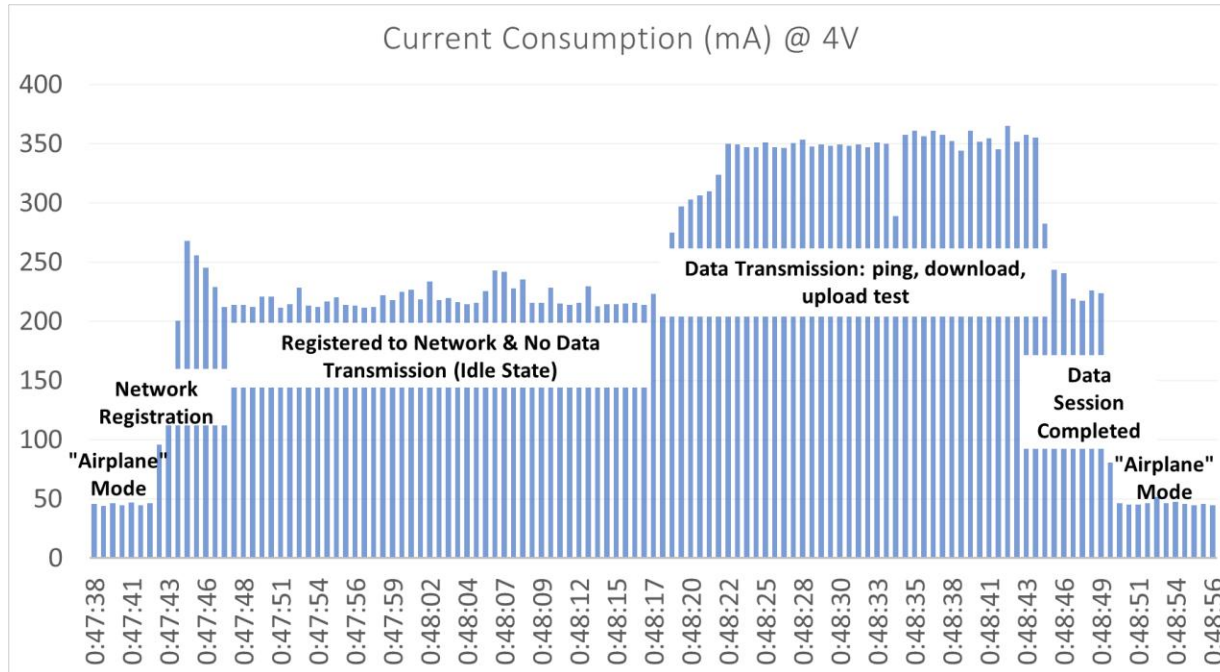
Date\KPI	LATENCY (ms)	JITTER (ms)	PACKET LOSS RATE (%)	DL THROUGHPUT (Mbps)	UL THROUGHPUT (Mbps)	Total Transferred Bytes (GB)
29/03/2022 15:00	48.75	1.28	0.02	252.56	65.11	9.18
29/03/2022 18:00	47.79	8.80	0.05	219.11	58.93	8.36
29/03/2022 21:00	48.83	1.42	0.00	253.25	65.09	9.17
30/03/2022 00:00	48.45	1.59	0.00	252.74	65.24	8.94
30/03/2022 03:00	48.71	1.22	0.00	252.84	64.90	9.14
Average: MALAGA Server	48.51	2.86	0.01	246.10	63.86	8.96
Average: ATHENS Server	126.04	10.62	0.33	245.42	58.79	9.20

- ✓ The data speed related KPIs close to the theoretical maximum (DL: 287 Mbps, UL: 80 Mbps)
- ✓ Computing and peripheral connection resources (RPI 4/USB 3.0) sustain the 5G requirements
- ✓ Reliability performance as determined by packet loss rates is as expected for Malaga Server
- ✓ Delay-centric performance needs further investigation for time-critical control applications

PROJECT RESULTS



MEASUREMENTS & LESSONS LEARNT (3/3): ENERGY CONSUMPTION PROFILING



- ✓ Background Consumption: 50 mA
- ✓ Network Attachment: 250 mA
- ✓ Data Session: 350 mA
- ✓ "Slow-Start" Data Session
- ✓ 1-sec granularity



Part II – Business Impact & Feedback

BUSINESS IMPACT



HOW DID FED4FIRE+ HELPED US

- ✓ Had free access to a 5G operational environment
 - Controlled
 - Unlimited testing capabilities
- ✓ Offered the opportunity to verify and benchmark the in-house MVP prototype in the 5G TRIANGLE facility
 - Validated 5G radio and IP connectivity in a private 5G cell
 - Performed a series of stress tests for critical KPIs: data speed, latency, reliability, energy consumption
 - Moved from lab to real-world



BUSINESS IMPACT



VALUE PERCEIVED

- ✓ Advanced the MVP to TRL6
- ✓ Leveraged the funding to finalize and evaluate the product MVP
- ✓ Used the technical results to obtain insights in potential 5G-IoT application support

ROADMAP

- ✓ Move to productization stage in next 9-18 months
- ✓ Anticipate to increase our IoT hardware market share by uniquely combining 5G communications and IoT computing technologies into a flexible Dev-Board
- ✓ Expand to new verticals

PROJECT FEEDBACK

USED RESOURCES & TOOLS

Wireless/5G/IoT testbeds		
	Triangle/PerformLTE (UMA)	YES <ul style="list-style-type: none">• Private 5G Cell based on Nokia's commercial radio equipment accessed through test SIM cards• DC Power Supply & Analyzer• Secure Local Network Resources (VPN)

<i>Tools</i>	<i>Used?</i>	<i>Please indicate your experience with the tools. What were the positive aspects? What didn't work?</i>
VPN	YES	Software (application), used for establishing secure connection with the TRIANGLE Testbed Local Network. It was provided by the Patron, worked perfectly with the click of one button in both Windows and Linux OSs.
Power Analyzer Automated Script	YES	Software (bash script) used for monitoring and recording energy consumption of the device-under-test. It was also Provided by the Patron, worked "out-of-the-box" and enabled the automated query of the power analyzer measurement module during an experiment.

PROJECT FEEDBACK

ADDED VALUE OF FED4FIRE+

- ✓ **State-of-the-Art hardware equipment** hardly found in the market or even non-available commercially, with support of multiple diverse technologies
 - Alternative Solutions: Either too expensive (e.g. AMARI STACK) or requiring significant effort to deploy and operate (e.g. OpenAirInterface5G)
- ✓ **Easy, full and secure remote access to the experimentation nodes**
- ✓ **Technical support** during the whole experimentation cycle
- ✓ **Test scripts** for automating/accelerating experimentation process

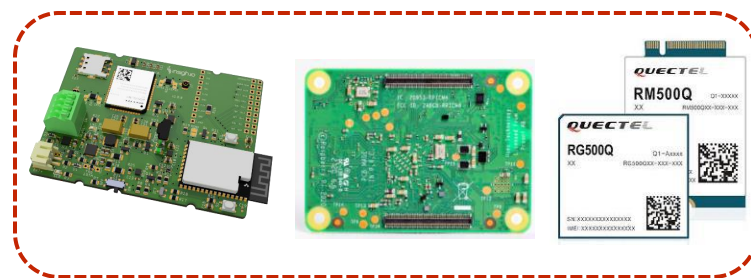
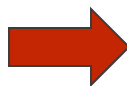
PROJECT CONCLUSION & FOLLOW-UP

THANKS TO THE EXPERIMENT WE CONDUCTED WITHIN FED4FIRE+ ...

... we were able to significantly advance the technology readiness level of our newly developed minimum viable product prototype related to 5G-IoT technologies.

We seized this opportunity to validate and demonstrate the prototype in a real-world private network offered by one of Fed4Fire+ state-of-the-art network facilities.

5G-IOT MVP



2023: FULLY EMBEDDED 5G-IOT PRODUCT



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European Union



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WWW.FED4FIRE.EU