3rd Edition

EWSN 2018 Dependability Competition

Awards Ceremony

Carlo Alberto Boano, Markus Schuss, and **Pablo Serrano**
Competition Co-Chairs

Why a Dependability Competition?

- Low-power wireless systems are increasingly more used in safety-critical application domains
  - Smart cities, health care, smart production, …
  - Those applications require dependable performance
  - The communication protocols need to deliver information in a reliable, efficient, and timely manner
- More than a decade of WSN / IoT research
  - Many solutions proposed by academia & industry

IPSN 2005

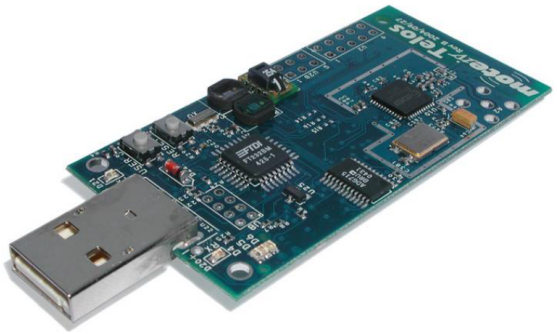
Telos: Enabling Ultra-Low Power Wireless Research

Joseph Polastre, Robert Szewczyk, and David Culler
Computer Science Department
University of California, Berkeley
Berkeley, CA 94720
{polastre,szewczyk,culler}@cs.berkeley.edu

Abstract— We present *Telos*, an ultra low power wireless sensor module ("mote") for research and experimentation. Telos is the latest in a line of motes developed by UC Berkeley to enable wireless sensor network (WSN) research. It is a new mote design built from scratch based on experiences with previous mote generations. Telos' new design consists of three major goals to enable experimentation: minimal power consumption, easy to use, and increased software and hardware robustness. We discuss how hardware components are selected and integrated in order to achieve these goals. Using a Texas Instruments MSP430 microcontroller, Chipcon IEEE 802.15.4-compliant radio, and USB, Telos' power profile is almost one-tenth the consumption of previous mote platforms while providing greater performance and throughput. It eliminates programming and support boards, while enabling experimentation with WSNs in both lab, testbed, and deployment settings.

I. Introduction

Wireless sensor networks are ideally suited for long-lived appli-



- More than a decade of WSN / IoT research
  - Many solutions proposed by academia & industry
  - Yet unclear which protocol(s) perform(s) best in a given application scenario
  - Their performance has rarely been benchmarked under the exact same settings

Why a Dependability Competition?

- Comparison typically carried out on public testbeds
  - No standard way to evaluate protocol performance
  - The use of the same testbed / setup does not imply comparable results

    → Protocol parameters need to be carefully tuned to the scenario at hand

- Need for a fair and objective comparison of protocol performance, especially in harsh RF environments

- Let's define a common scenario and let the different solutions compete with each other!

EWSN Dependability Competition Series

- 1st edition
  @ EWSN 2016
  (Graz, Austria)

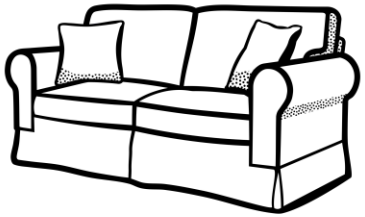
- 2nd edition
  @ EWSN 2017
  (Uppsala, Sweden)

- 3rd edition
  @ EWSN 2018
  (Madrid, Spain)

New Format (i)

- The first two editions were essentially 48-hours hackathons

New Format (i)



- This year's competition was run remotely over a 2-months time window

August 2017

- Call for competitors published

October 2017

- Competition entry deadline

Nine teams and 44 contestants from both academia and industry

China: Shanghai Adv. Res. Inst., ShanghaiTech Univ., Univ. of Chinese Academy of Sciences
France: University of Clermont-Auvergne
Germany: University of Oldenburg, Infineon Technologies, BMW, eesy-innovation GmbH, Airbus Group, RWTH Aachen University
Italy: University of Trento, Bruno Kessler Foundation
Japan: University of Tokyo
Sweden: Chalmers University of Technology
Switzerland: CSEM, ABB Corporate Research
United Kingdom: Toshiba Research Europe Limited

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Team 01: B. Al Nahas, O. Landsiedel
Team 02: X. Ma, P. Zhang, W. Tang, X. Li, W. He, F. Zhang, J. Wei, O. Theel
Team 03: A. Escobar, F. Moreno, B. Saez, A. Cabrera, J. Garcia, F. Cruz, U. Ruiz, A. Corona, J. Klaue, D. Tati
Team 04: C. Rojas, J.D. Decotignie
Team 05: M. Trobinger, T. Istomin, A.L. Murphy, G.P. Picco
Team 06: J. Wang, H. Tall, G. Chalhoub
Team 07: C.H. Liao, T. Sakdejayont, M. Suzuki, Y. Narusue, H. Morikawa
Team 08: U. Raza, Y. Jin, A. Stanoev, M. Sooryiabandara
Team 09: P. Sommer, Y.A. Pignolet, S. Marinkovic, A. Monot, M. Kabir-Querrec, R. Birke

New Format (i)

Constructive interference & flooding

2017

Nine teams and 44 contestants from both academia and industry

Team 01: Aggressive Synchronous Transmissions with In-network Processing for Dependable All-to-All Communication
Team 02: Using Enhanced OFPCOIN to Monitor Multiple Concurrent Events under Adverse Conditions
Team 03: BigBangBus
Team 04: Synchronous Transmissions + Channel Sampling = Energy Efficient Event-Triggered Wireless Sensing Systems
Team 05: CRYSTAL Clear: Making Interference Transparent
Team 06: Smart flooding with Multichannel for Industrial Wireless Sensor Networks
Team 07: Wireless-Transparent Sensing Platform
Team 08: CROWN: Concurrent ReceptiOns in Wireless Sensor and Actuator Networks
Team 09: Energy-Efficient Many-to-Many Communication with Channel-Hopping

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August 2017

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October 2017

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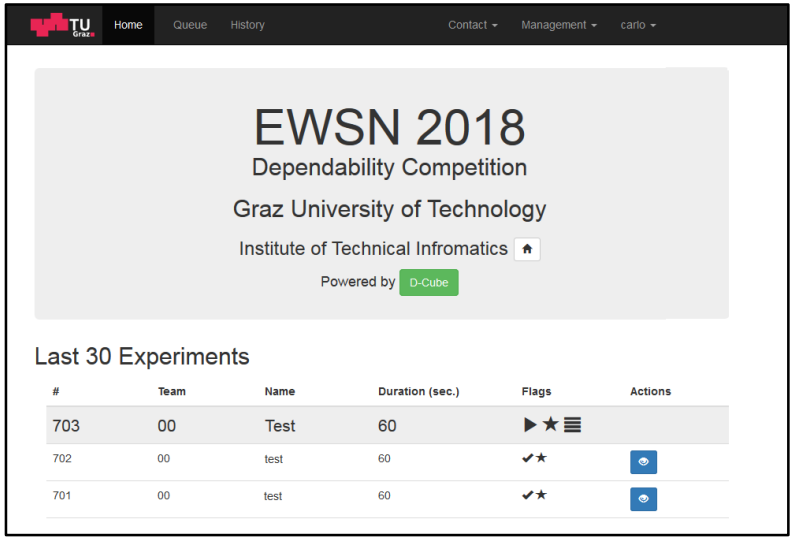
December, 1 2017

- Remote preparation phase begins

February, 1 2018

- Remote preparation phase ends
  - All teams submit a final firmware to be evaluated

New Format (i)



- Access to testbed facility for experimenting
- Blog to keep contestants up to date about logistics and latest news
- Slack group for quick interaction between contestants and organizers

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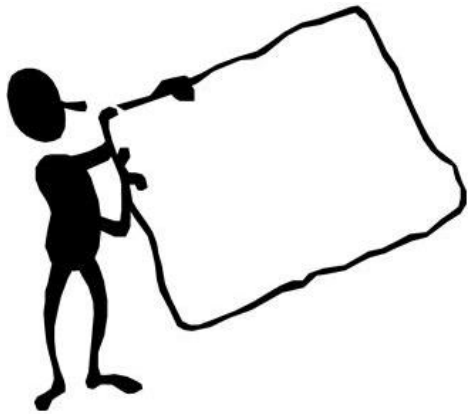
February 2-12, 2018

- Evaluation phase
  - Final firmware of all teams extensively tested (Results presented now!)

February 15, 2018

- Award ceremony and poster session
  - Right after this session!

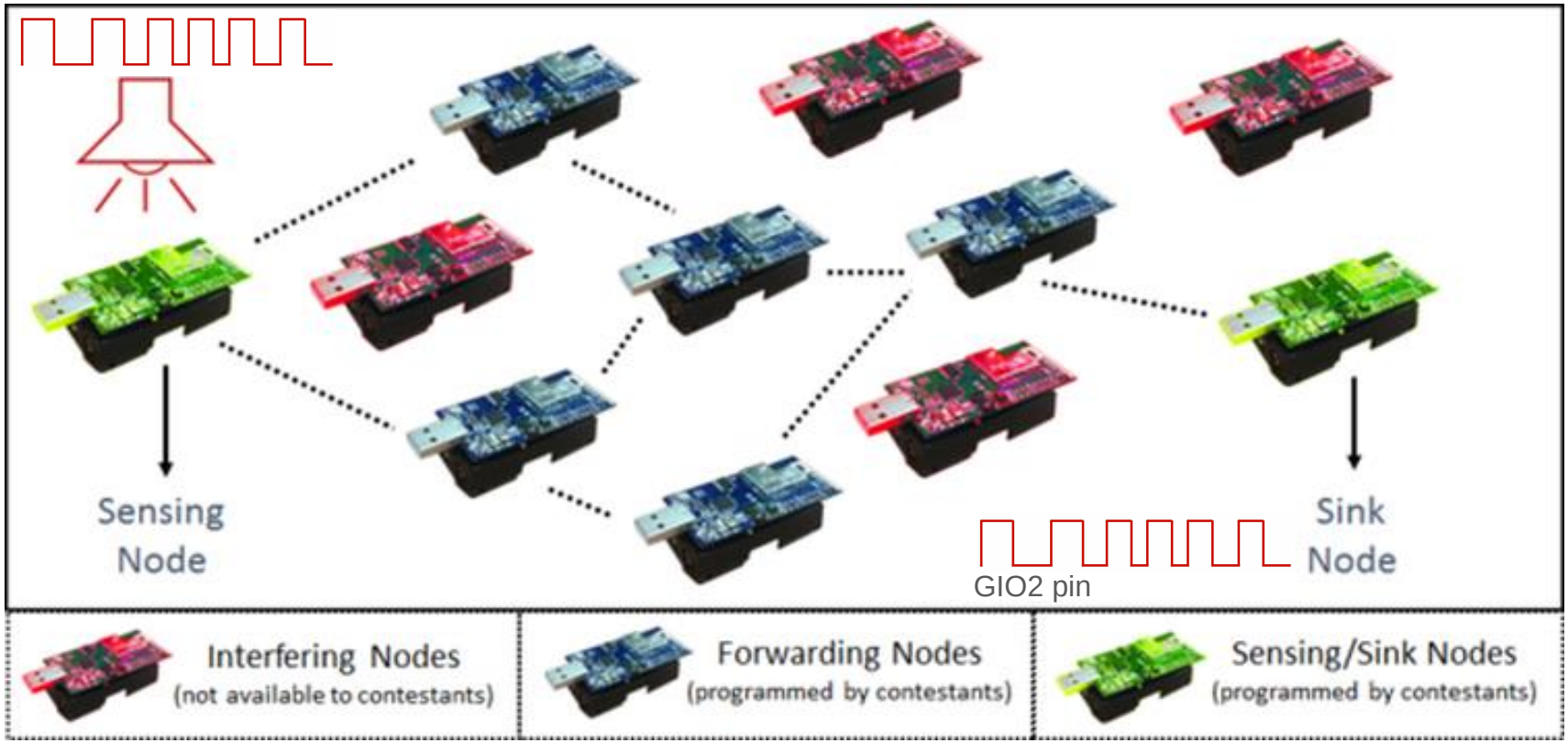


New Format (ii)

2016: very dense network

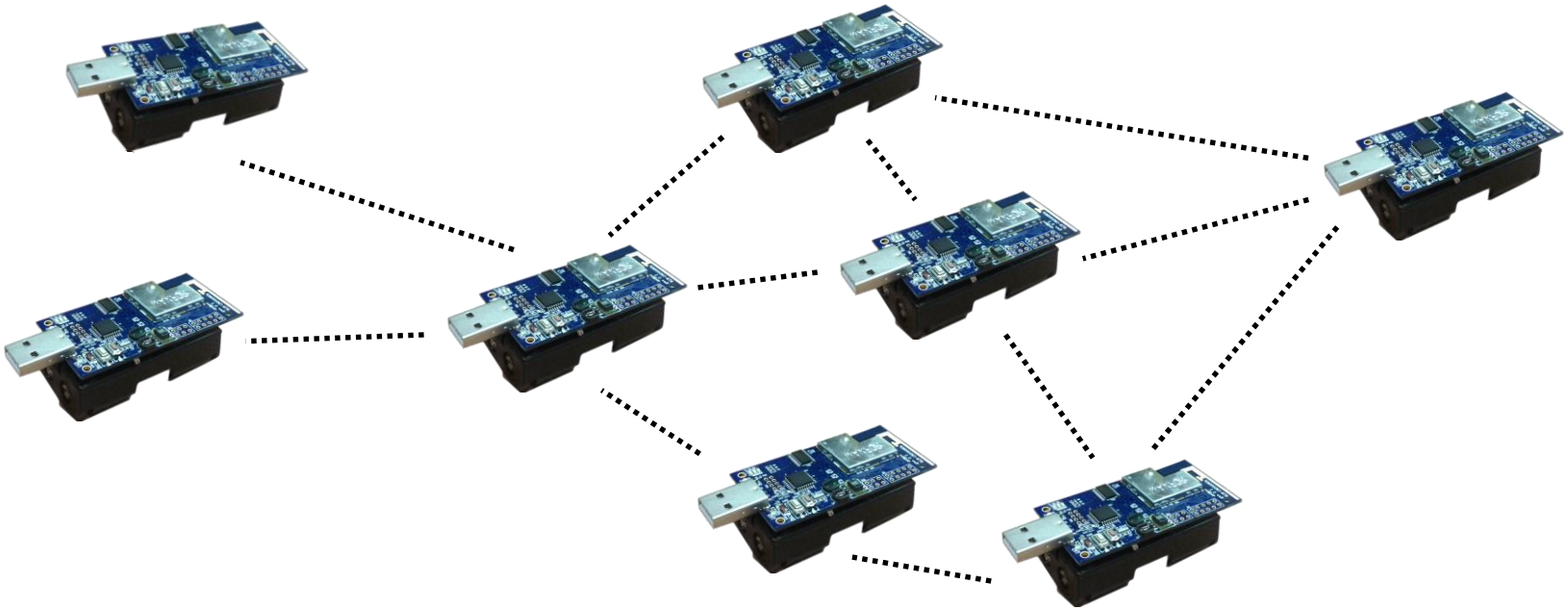
2017: very sparse network

- New evaluation scenario
  - The past two editions focused on a *single* source node monitoring *one* event and forwarding this information to a *single* destination node over a multi-hop network



New Format (ii)

- New evaluation scenario: reporting of multiple events from/to several nodes
  - In this year's scenario, *many* source nodes monitor *several* events and need to forward this information to *one or more* destinations over a multi-hop network



New Format (ii)

Case 1: P2P (point-to-point)
(from node 1 to node 2)

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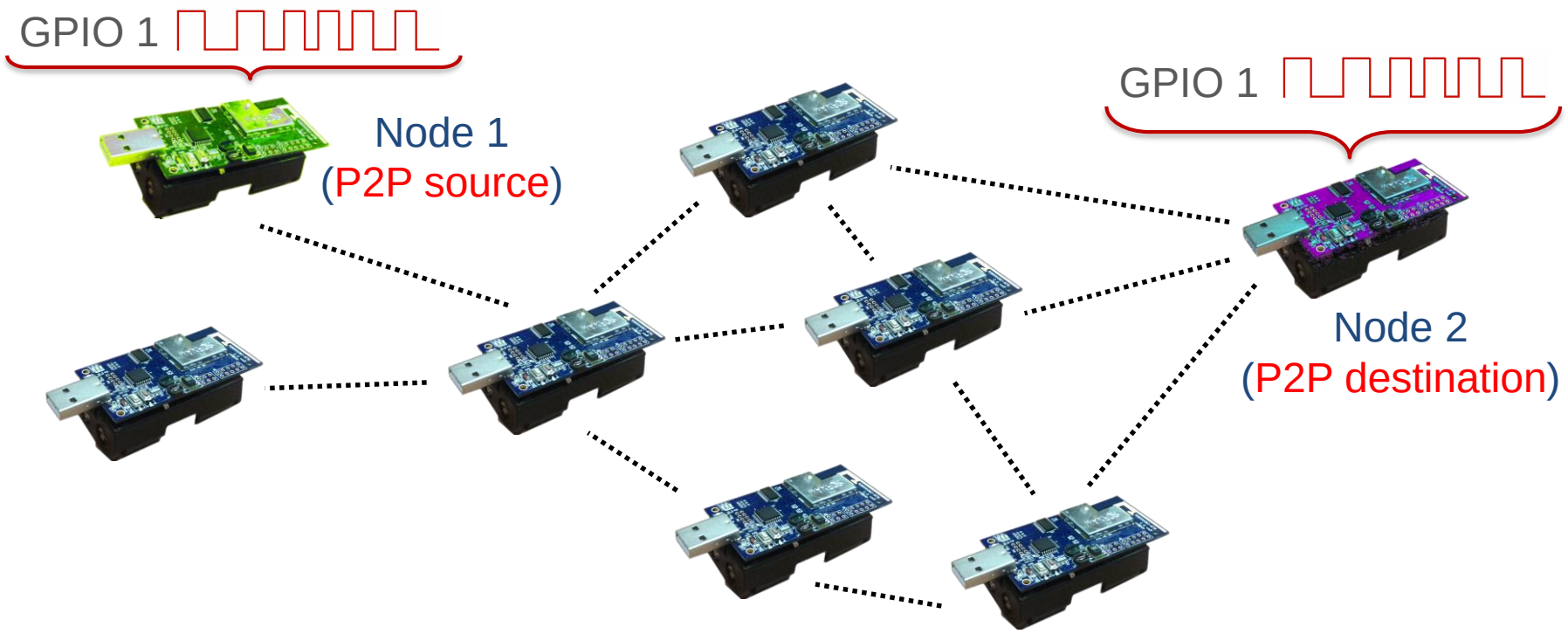
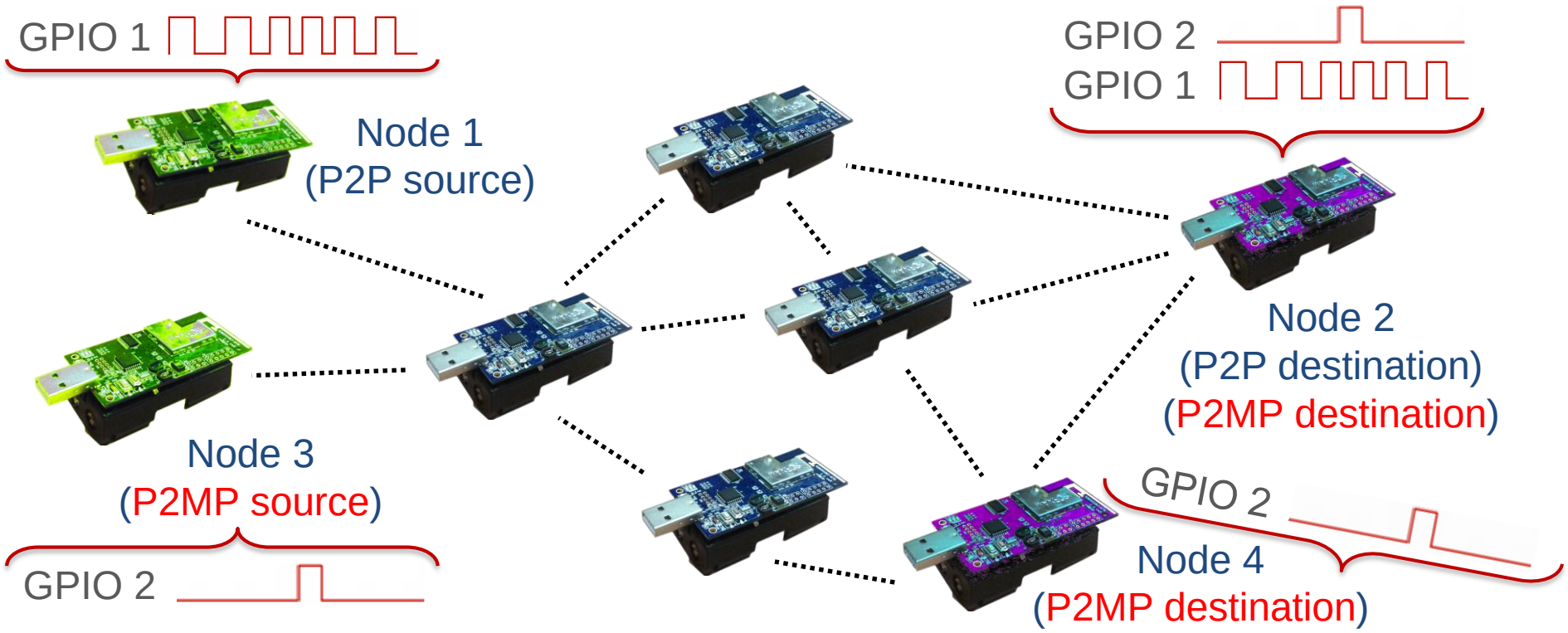


New Format (ii)

Case 2: P2MP (point-to-multipoint)
(from node 3 to nodes 2 and 4)

- New evaluation scenario: reporting of multiple events from/to several nodes
  - In this year's scenario, *many* source nodes monitor *several* events and need to forward this information to *one or more* destinations over a multi-hop network



New Format (ii)

Case 3: MP2P (multipoint-to-point)
(from nodes 5,6,7 to node 8 [OR])

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  - In this year's scenario, *many* source nodes r
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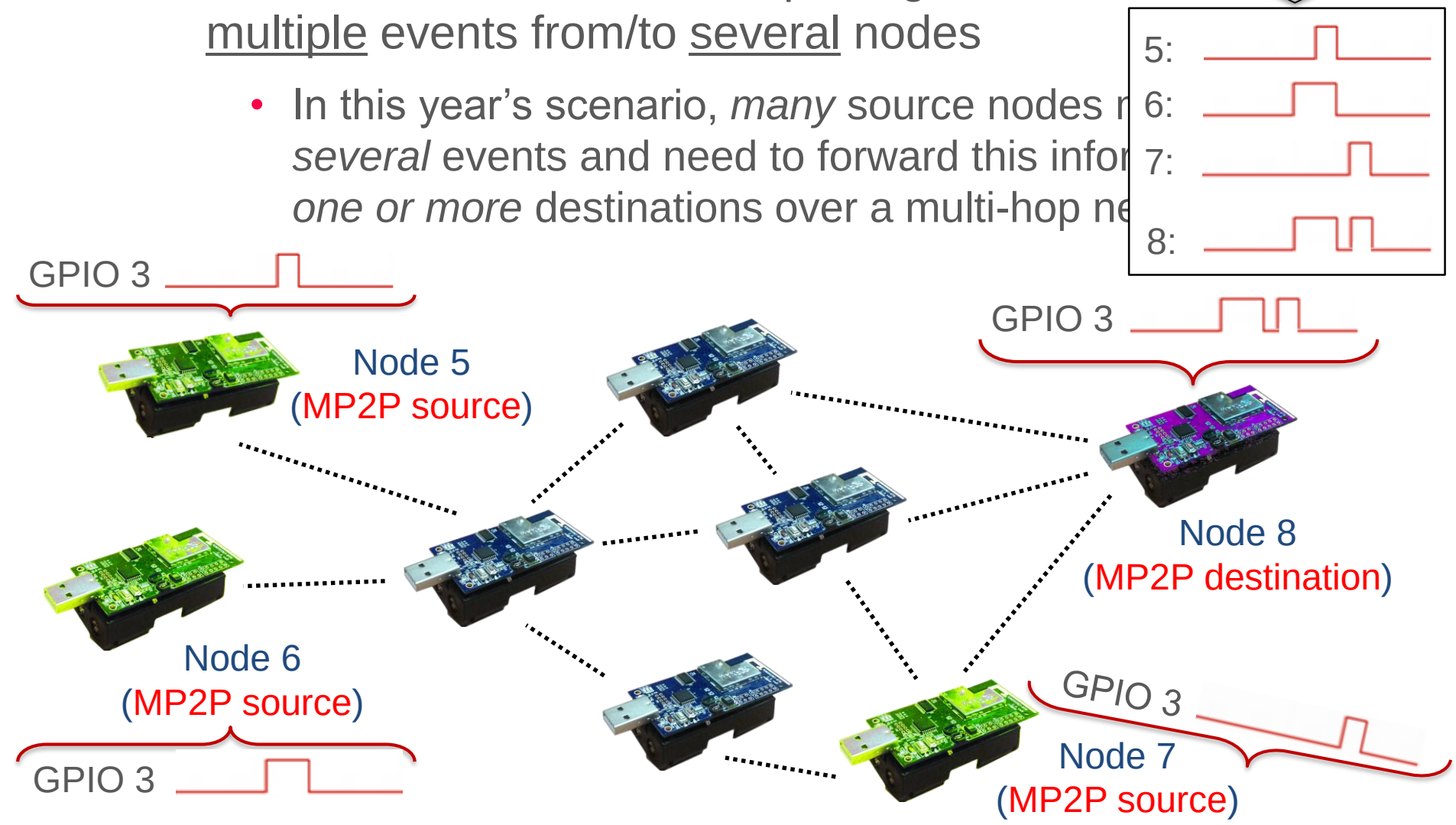
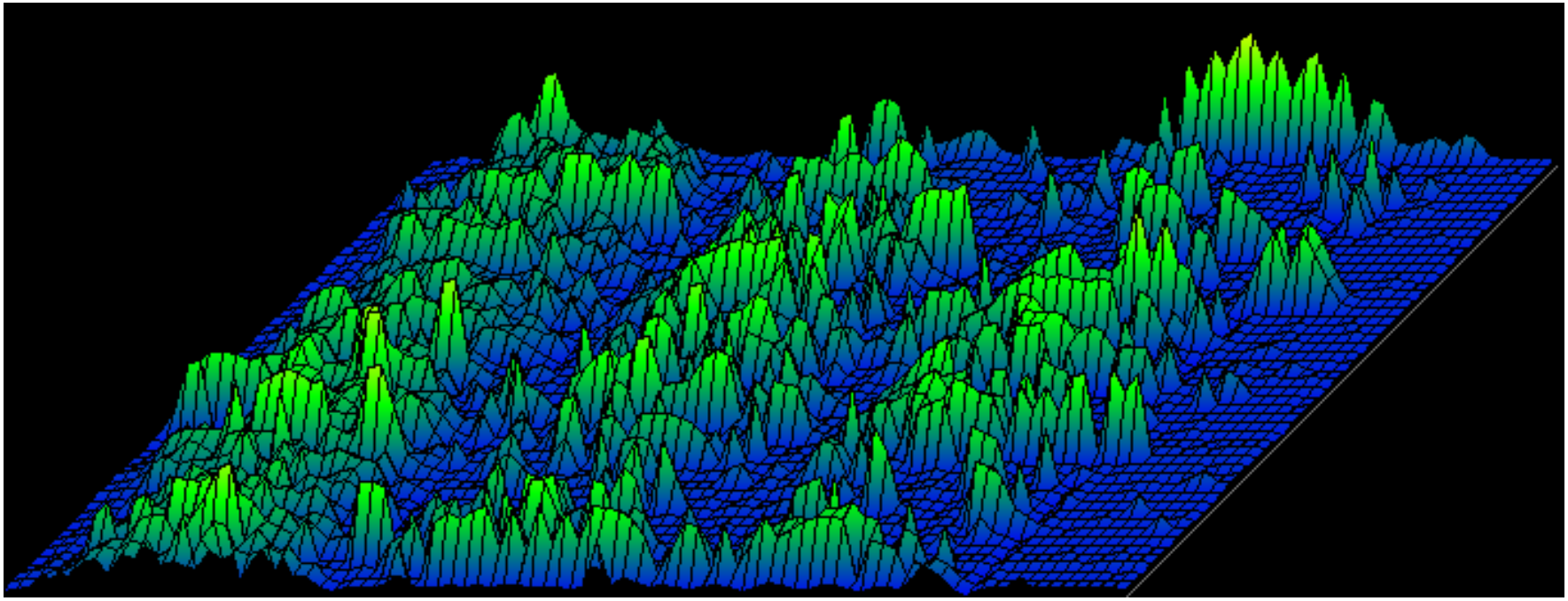
    one or more destinations over a multi-hop ne



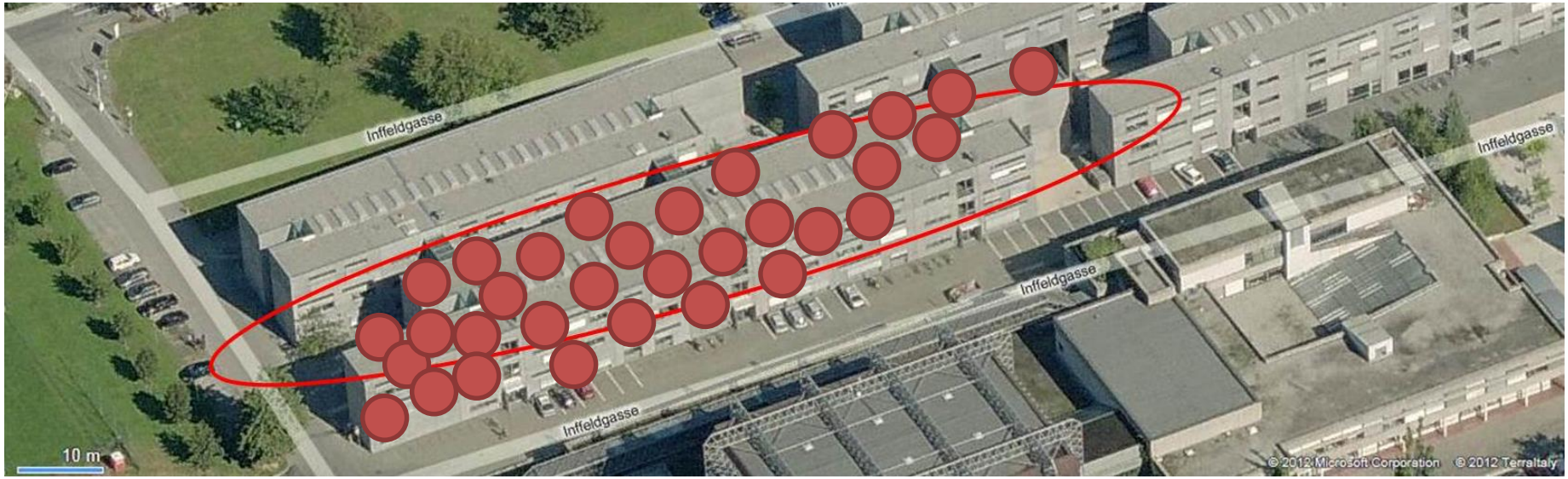
New Format (iii)

- Very challenging RF environment ⚡
  - Interference is no longer generated using IEEE 802.15.4 nodes running JamLab, as in the previous years
  - We made use of up to several Raspberry Pi3 nodes generating Wi-Fi traffic with different characteristics



Evaluation Scenario

- 51 nodes in total over an area of ~ 1000m^2
  - 11 sources, 13 destinations, 27 forwarding nodes
  - 3x P2P, 3x P2MP, 2x MP2P
- Nodes deployed over multiple floors in Inffeldgasse 16 (Institute for Technical Informatics of TU Graz, Austria)
  - University offices, seminar rooms, and labs



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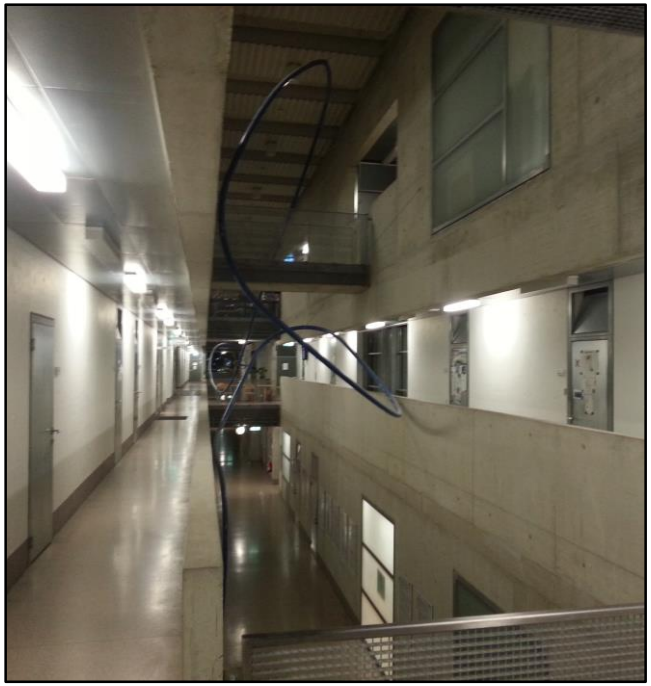

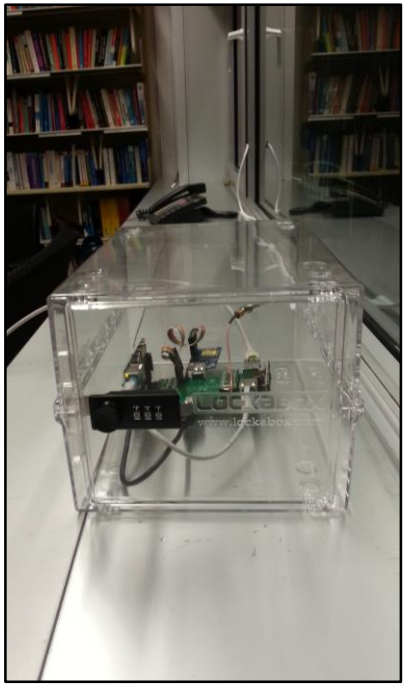

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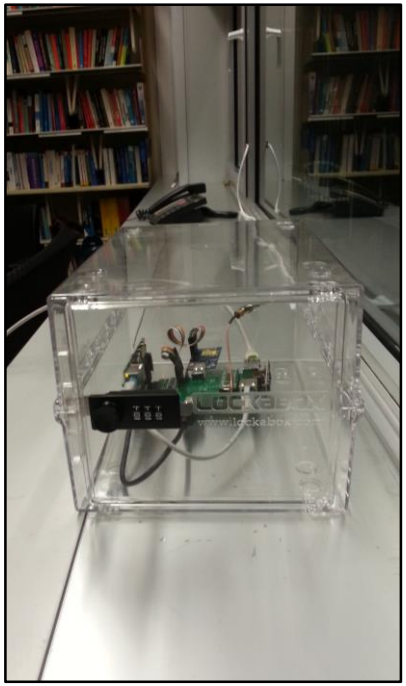
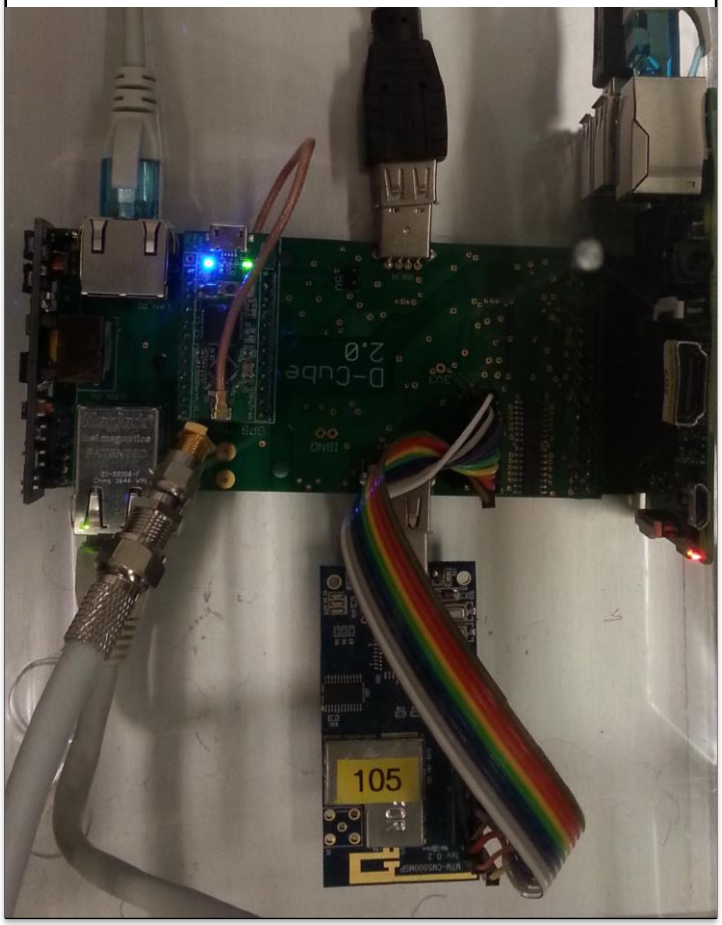


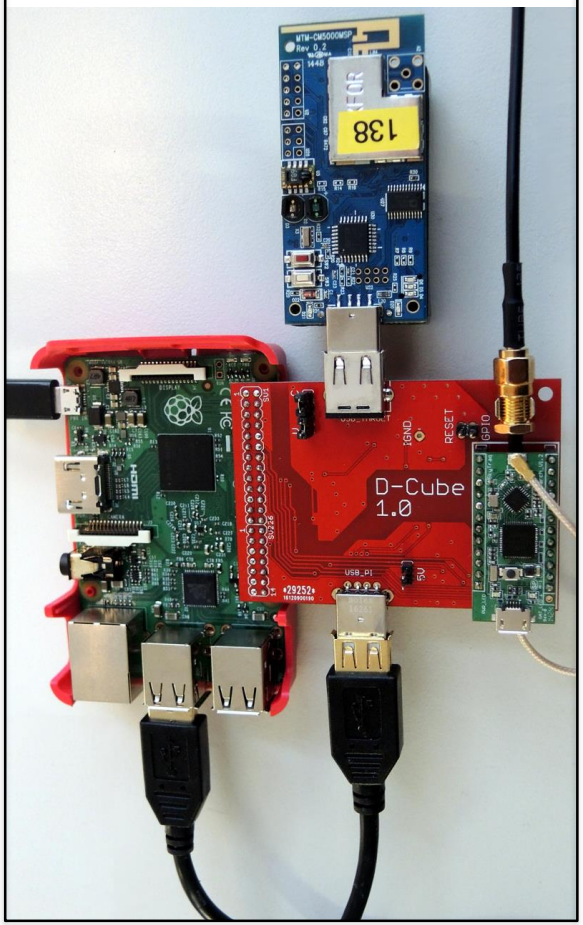
Benchmarking Tool: D-Cube

- More info: http://iti.tugraz.at/d-cube

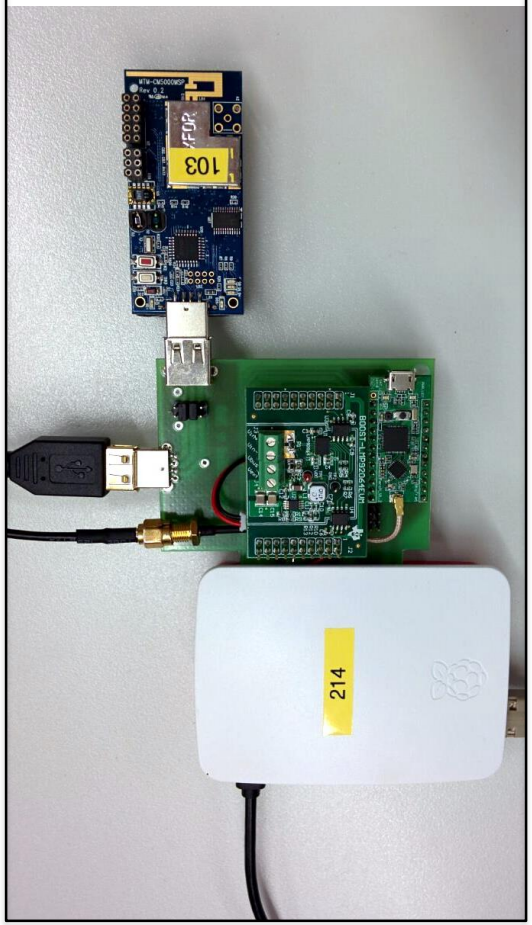
This year's version (EWSN'18)



EWSN'17 version



EWSN'16 version



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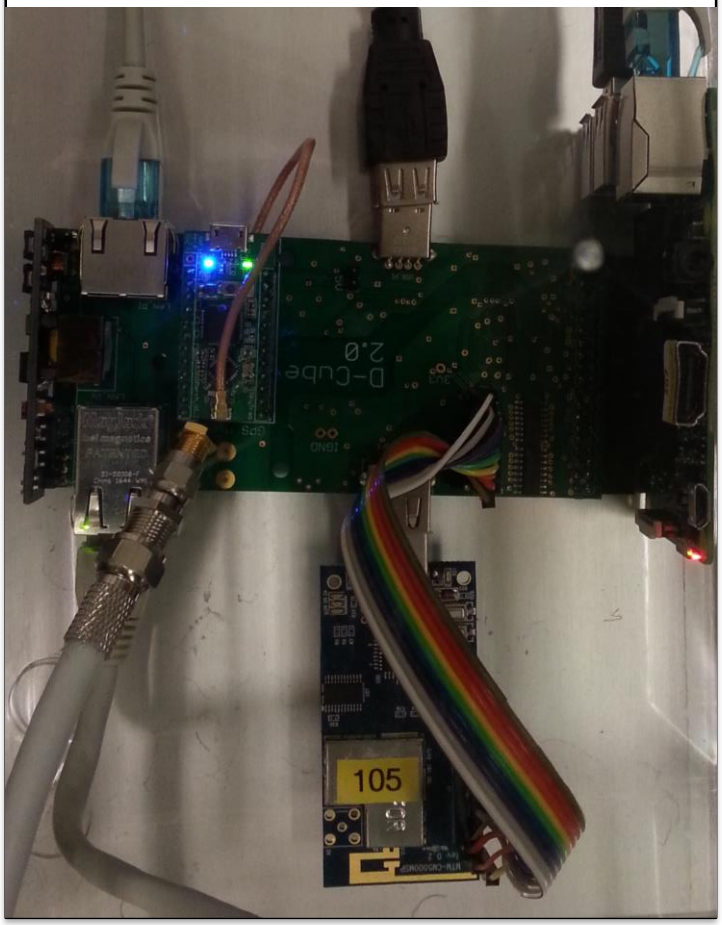
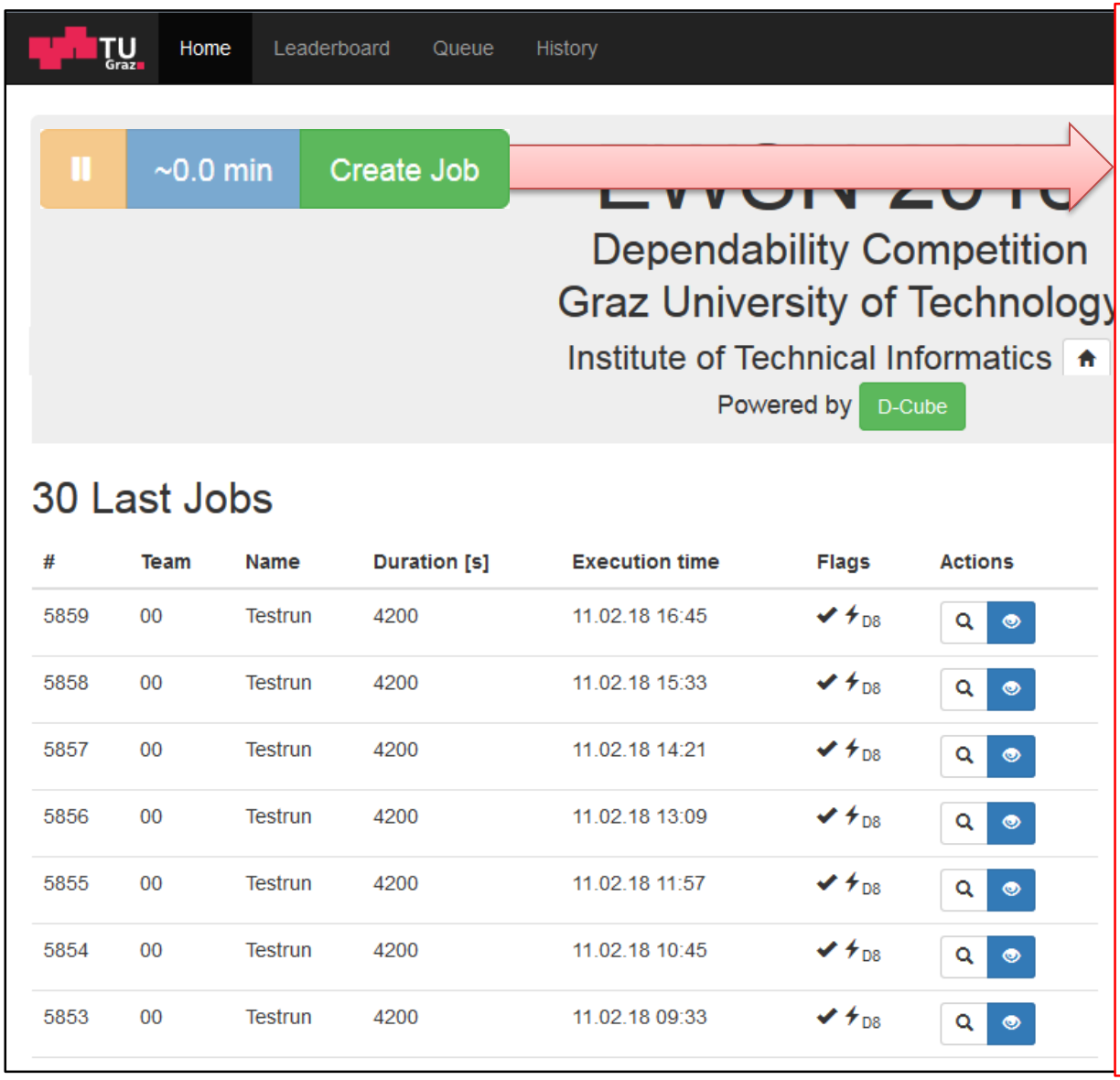
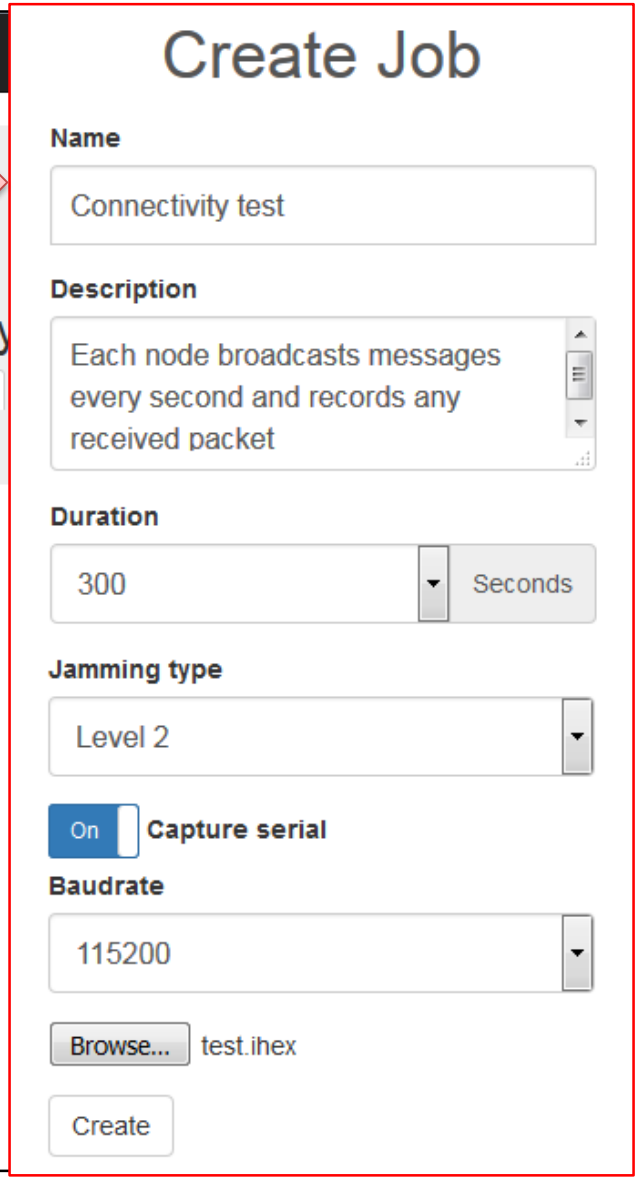
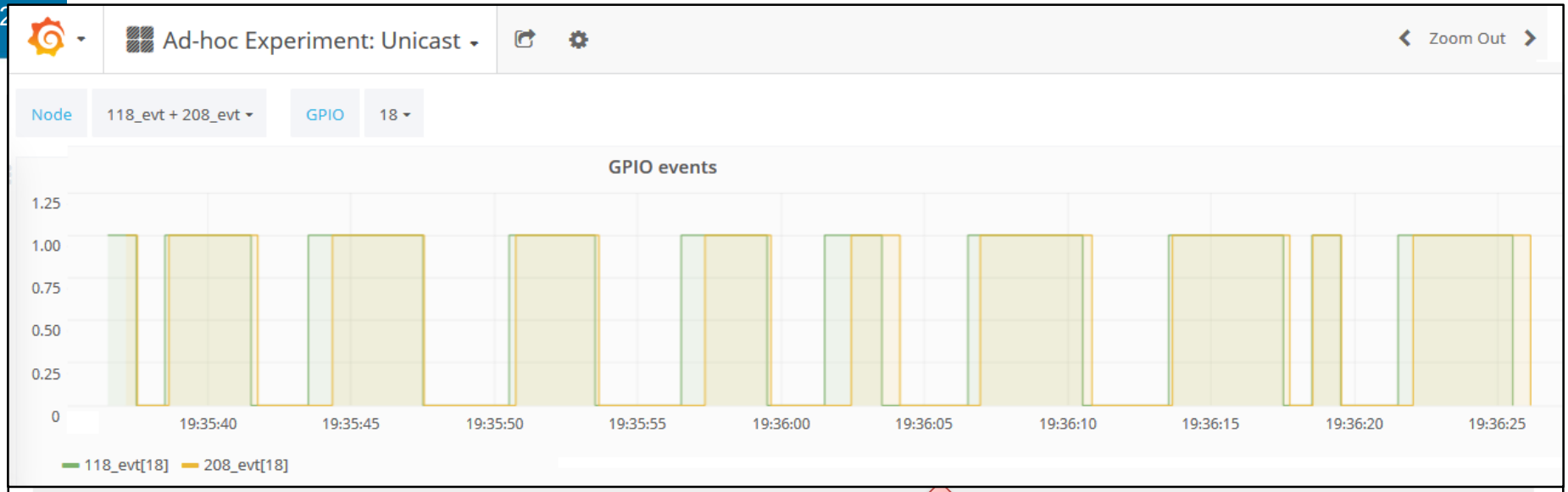


- Raspberry Pi3 with custom made add-on card
  - → Latency profiling: GPS module with timestamping support
  - → Energy profiling: simultaneous sampling ADC @125 kHz
  - → Support for both GPIO profiling and actuation
  - → Target platform: MTM-CM5000-MSP nodes (TelosB replicas with 10 kB RAM)

Benchmarking Tool: D-Cube





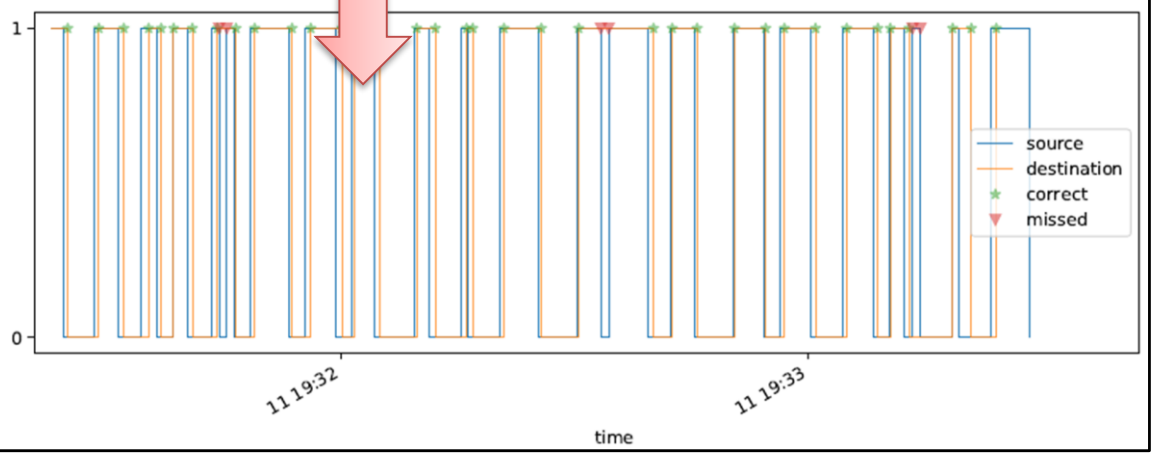


30 Last Jobs

#	Team	Name	Duration [s]	Execution time	Flags	Actio
5859	00	Testrun	4200	11.02.18 16:45	✔ D8	

Performance Metrics

Metric	Result
Latency [ms]	506.5
Reliability [%]	87.5
Energy [J]	291.3



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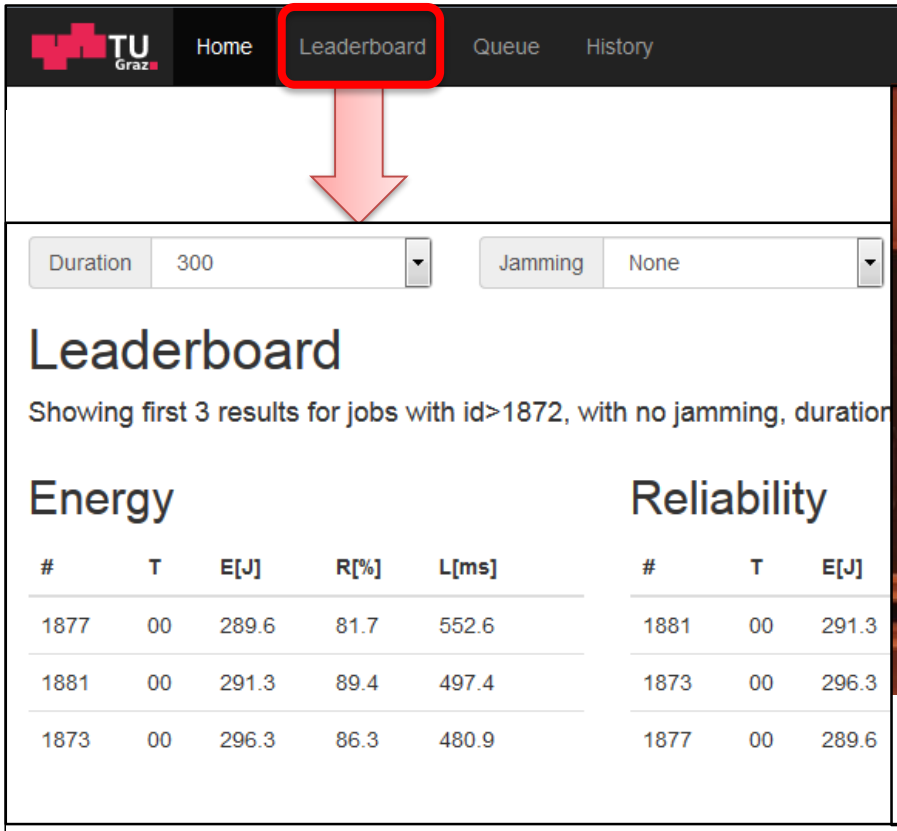
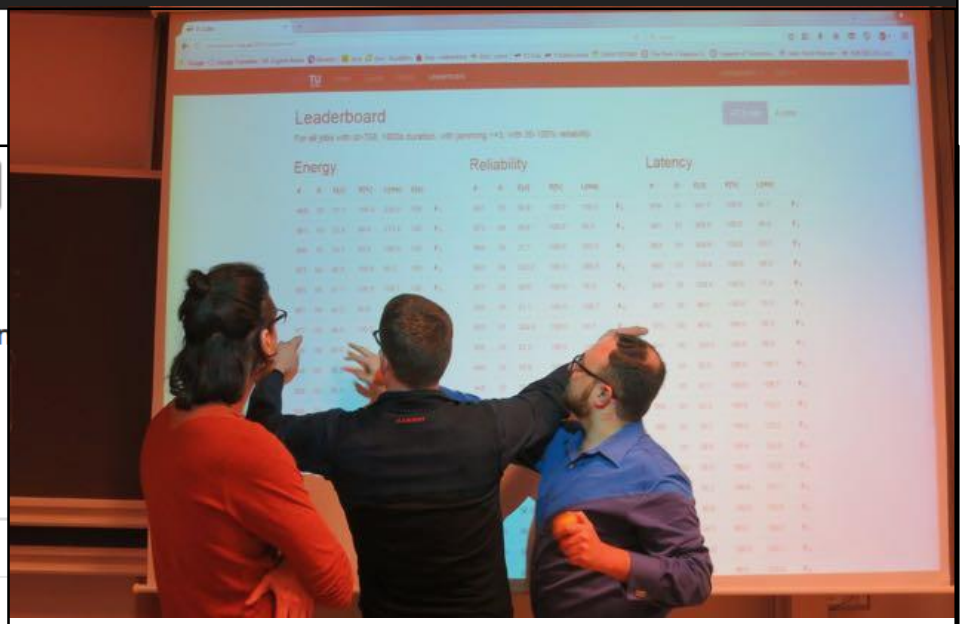
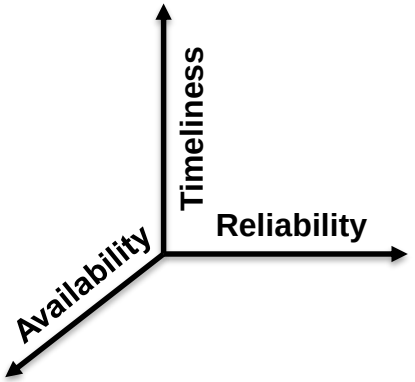




Contestants comparing the results from the leaderboard during EWSN'17 in Uppsala

- Results of all teams were summarized on a public leaderboard
  - As shown in the previous editions, knowledge of each other's performance is one of the salient aspects of the competition

Evaluation Metrics



- Solutions have been evaluated according to three criteria:
  1. Reliability of transmissions
     → Number of GPIO events correctly reported
     → In case wrong events are reported, a penalty is introduced (i.e., wrong events may decrease reliability down to 0)
  2. End-to-end latency
     → Time to communicate a GPIO event to the destination
  3. Energy-efficiency
     → Power consumed by all nodes in the network (measured in hardware every 20 µs)

- The team that performs best across all categories wins
  - Relative differences between solutions are considered
  - Reliability has a higher weight than the other two metrics

Evaluation Procedure

- The firmware of each team has been evaluated for 750 minutes under different RF conditions
  - No interference
  - Interference bursts of different duration
  - Interference of different channels
  - …
- We have evaluated the performance of the competing teams in each individual RF condition and in each individual scenario (P2P, P2MP, MP2P)
  - We will show the strengths & weaknesses of each solution
  - The winner is selected by considering the average performance across all scenarios and RF conditions

Evaluation Procedure

- Top three teams have been running for an additional 400 minutes
  - Make sure there is no abnormal variance in the results
  - Results were very repeatable! Some examples:

Reliability [%]:	Energy [J]:	Latency [ms]:
74.22 ± 0.60	7376.22 ± 0.69	110.88 ± 0.12
99.61 ± 0.04	6058.99 ± 4.94	204.15 ± 1.92
99.11 ± 0.13	7040.13 ± 3.43	105.77 ± 3.32
…	…	…

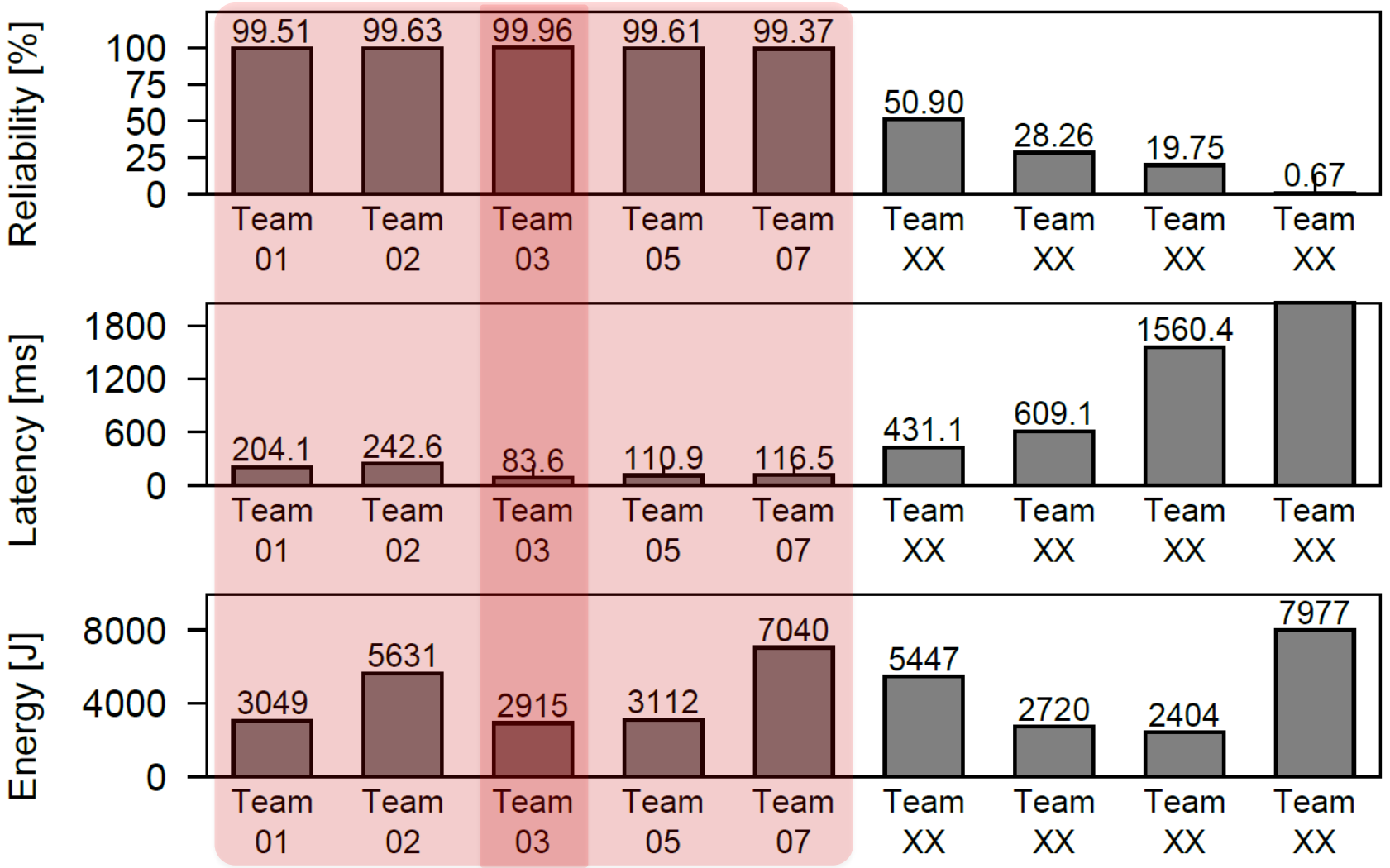
- Best 3 teams are awarded with certificate & cash award
  - 1st place: 750€
  - 2nd place: 500€
  - 3rd place: 250€

Evaluation Results

(And the best teams are…)

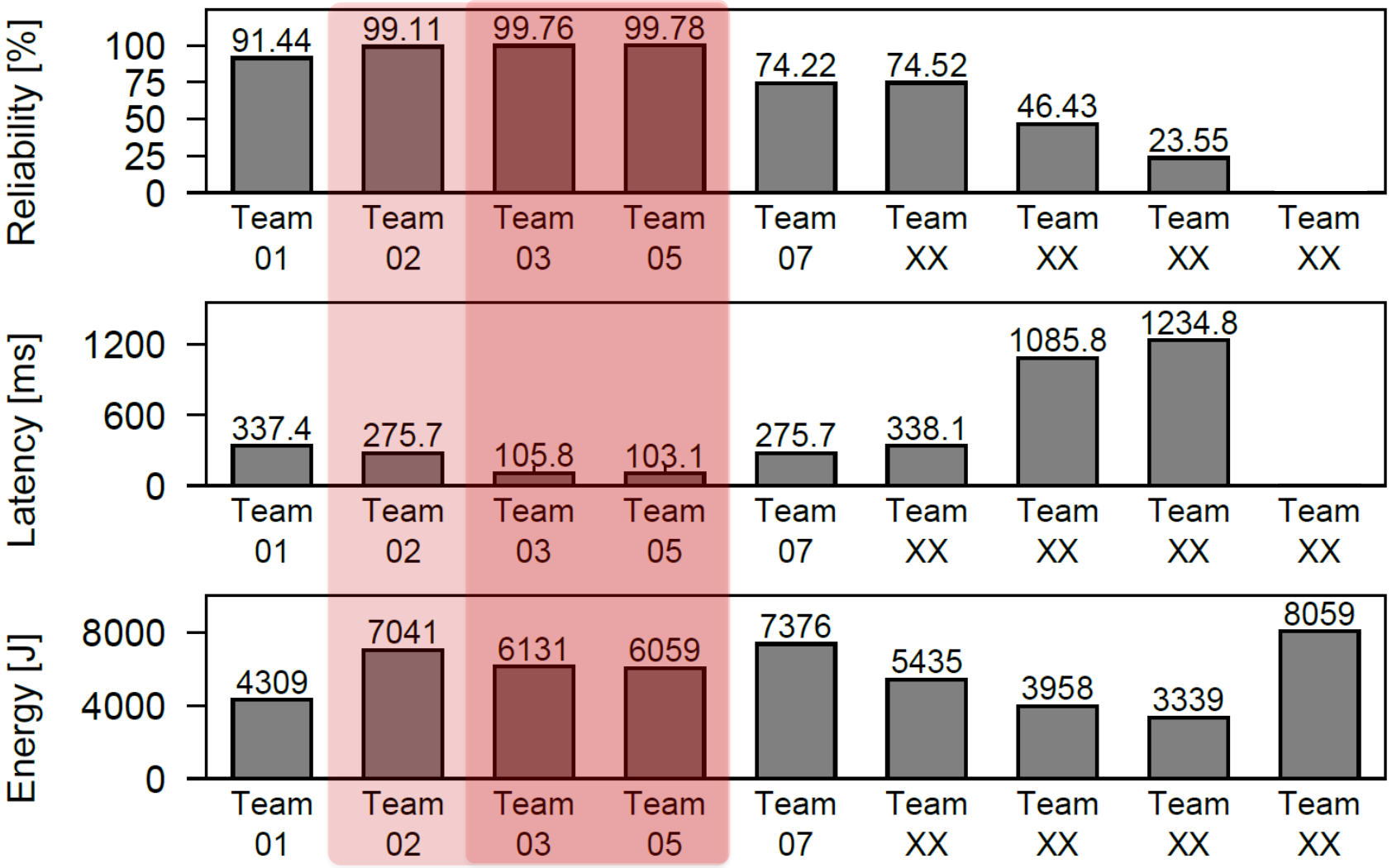
Scenario 1: Absence of Interference

- Five teams with outstanding performance



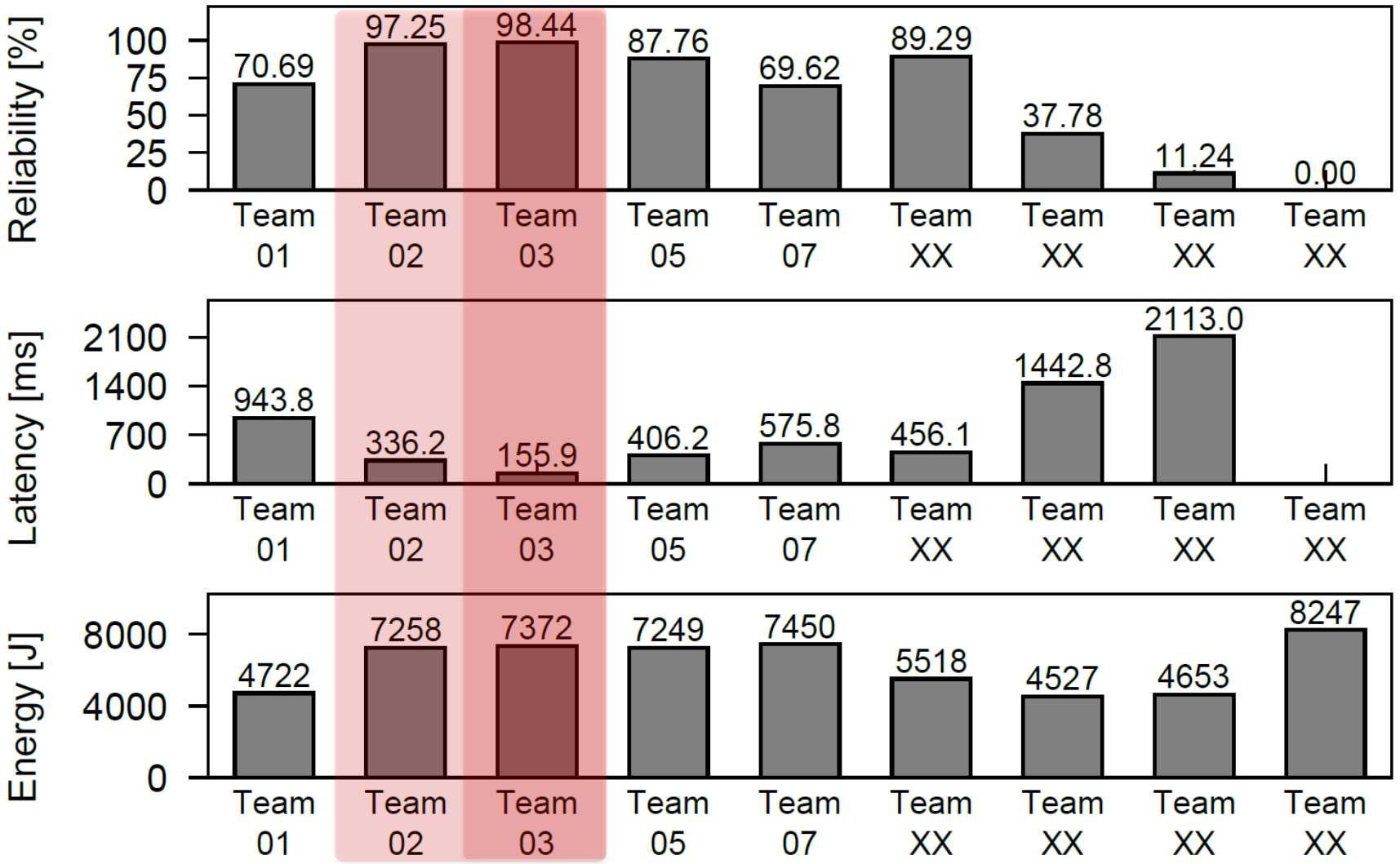
Scenario 2: Introducing Interference

- Bursts of fixed duration, same fixed channel for all jammers



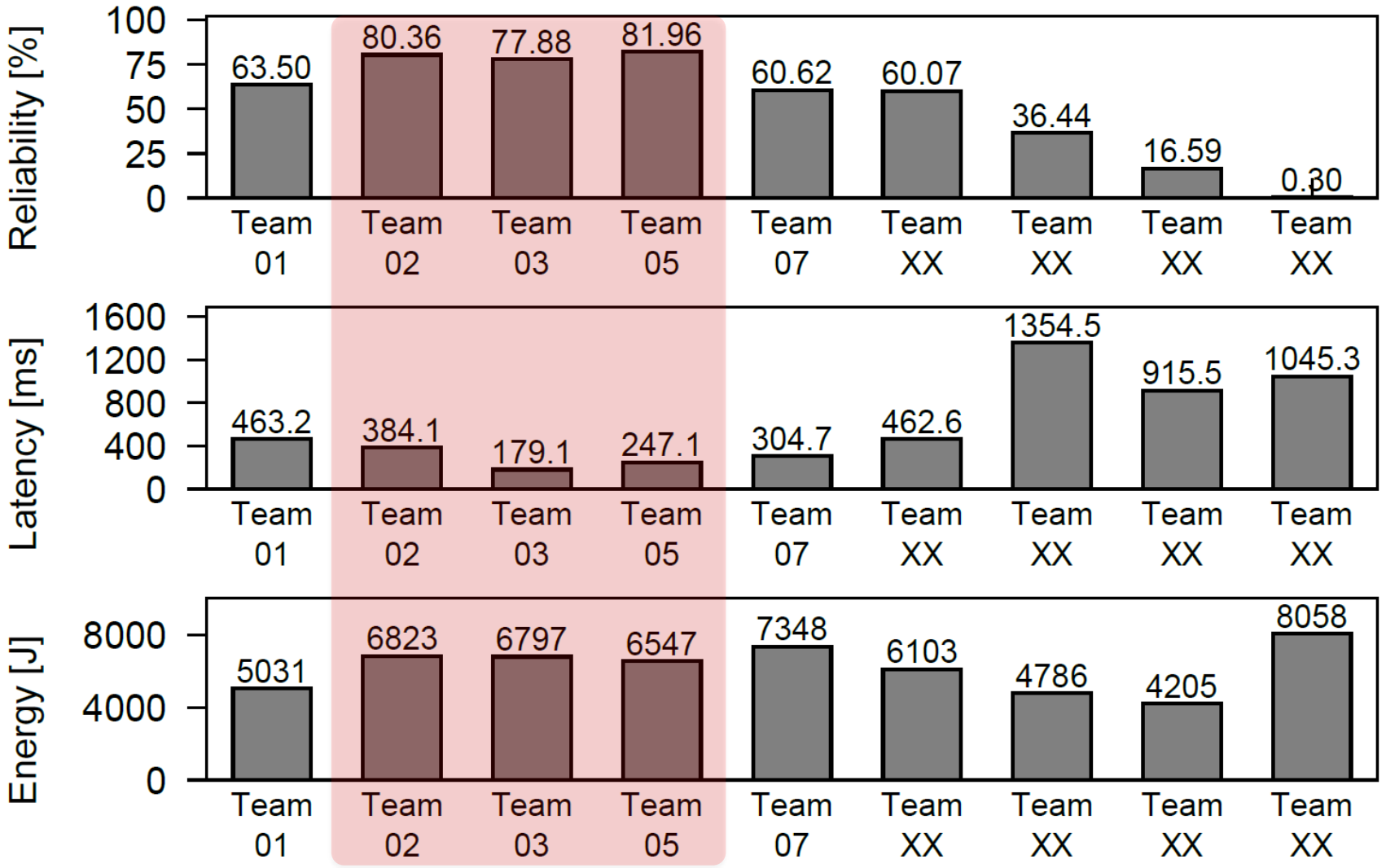
Scenario 3: Introducing Interference

- Bursts of fixed duration, fixed random channel for all jammers



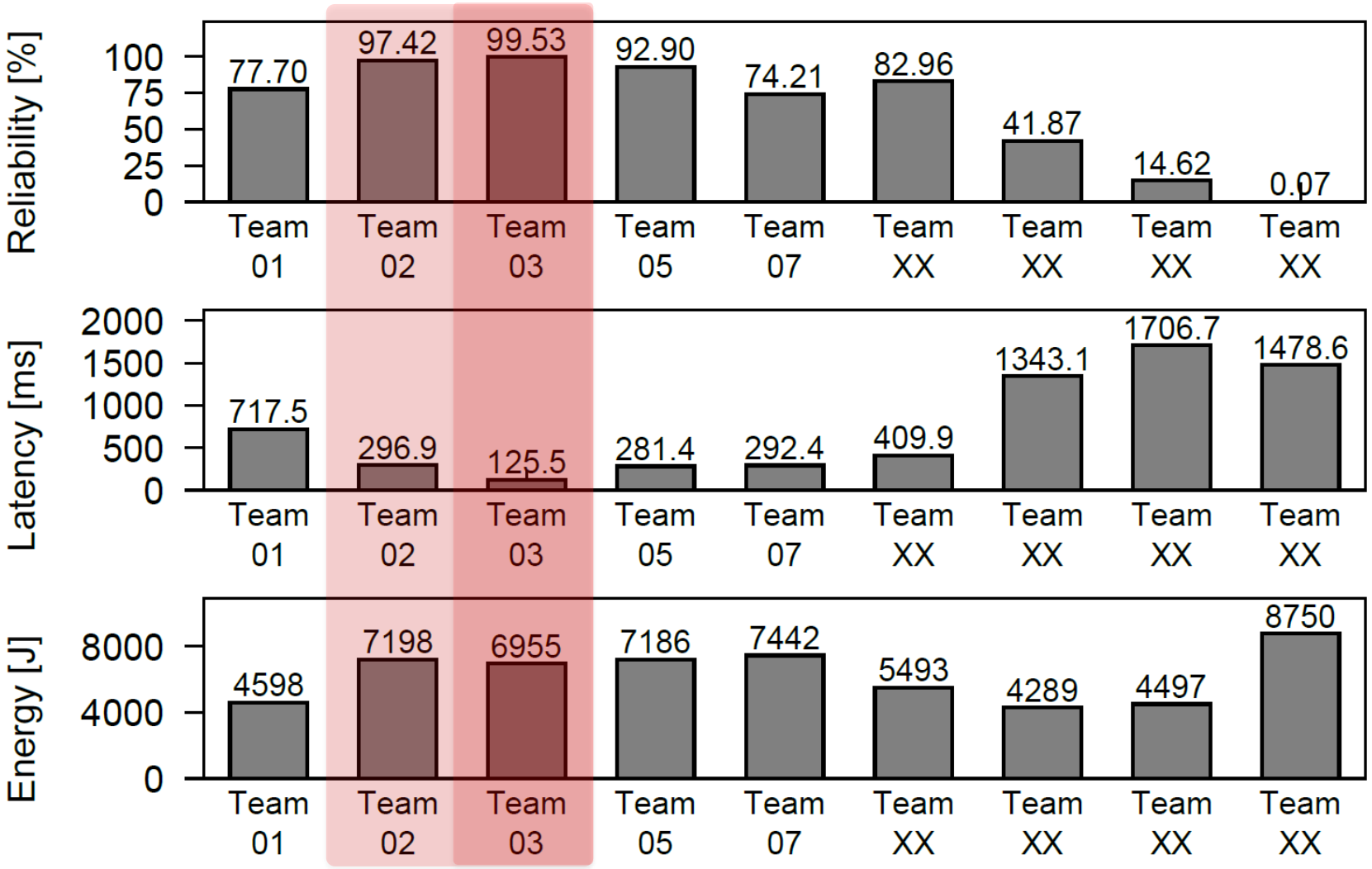
Scenario 4: Increasing Interference

- Bursts of varying duration, fixed random channel for all jammers



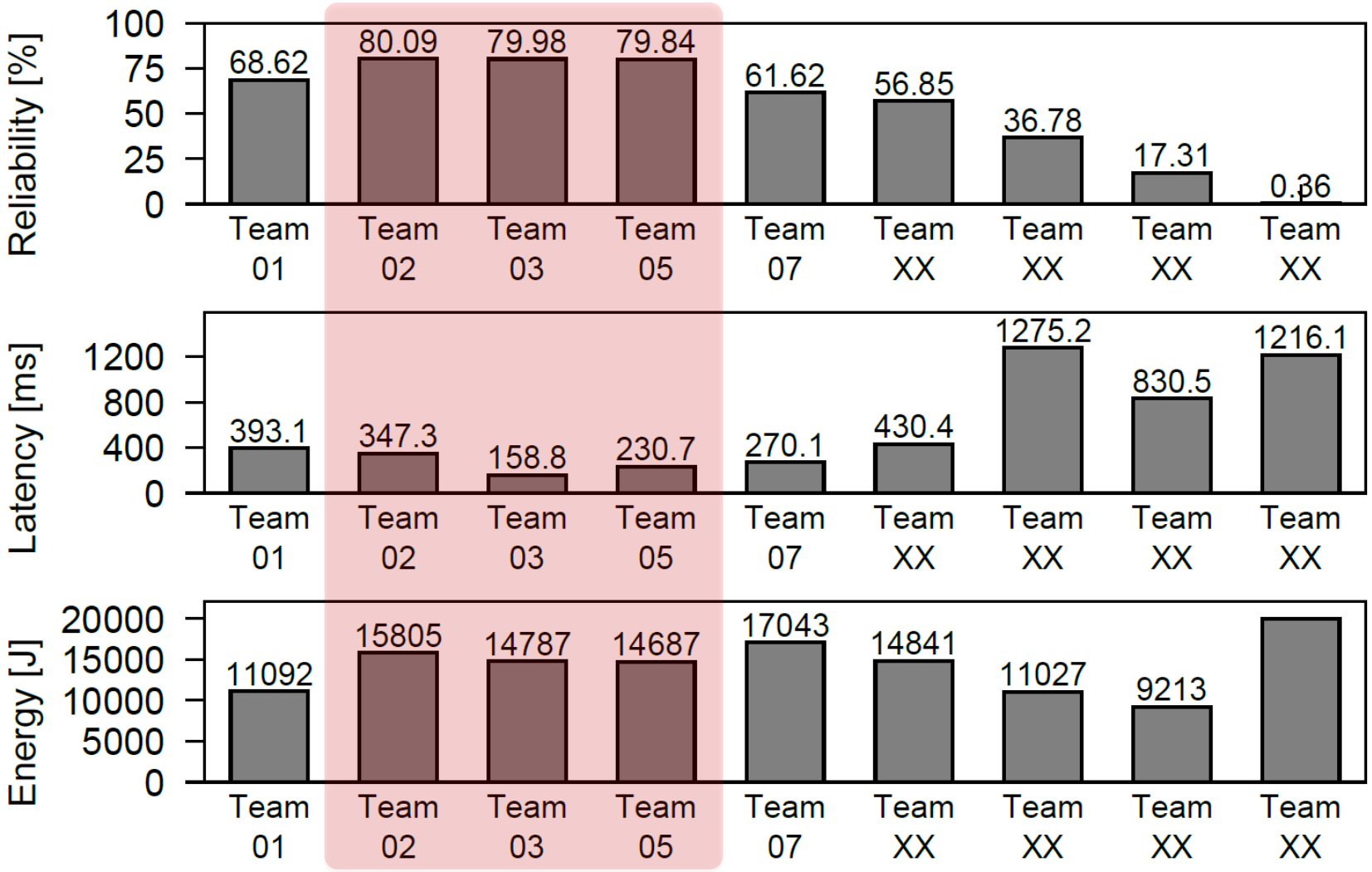
Scenario 5: Varying Interference

- Bursts of fixed duration, dynamic channel for all jammers



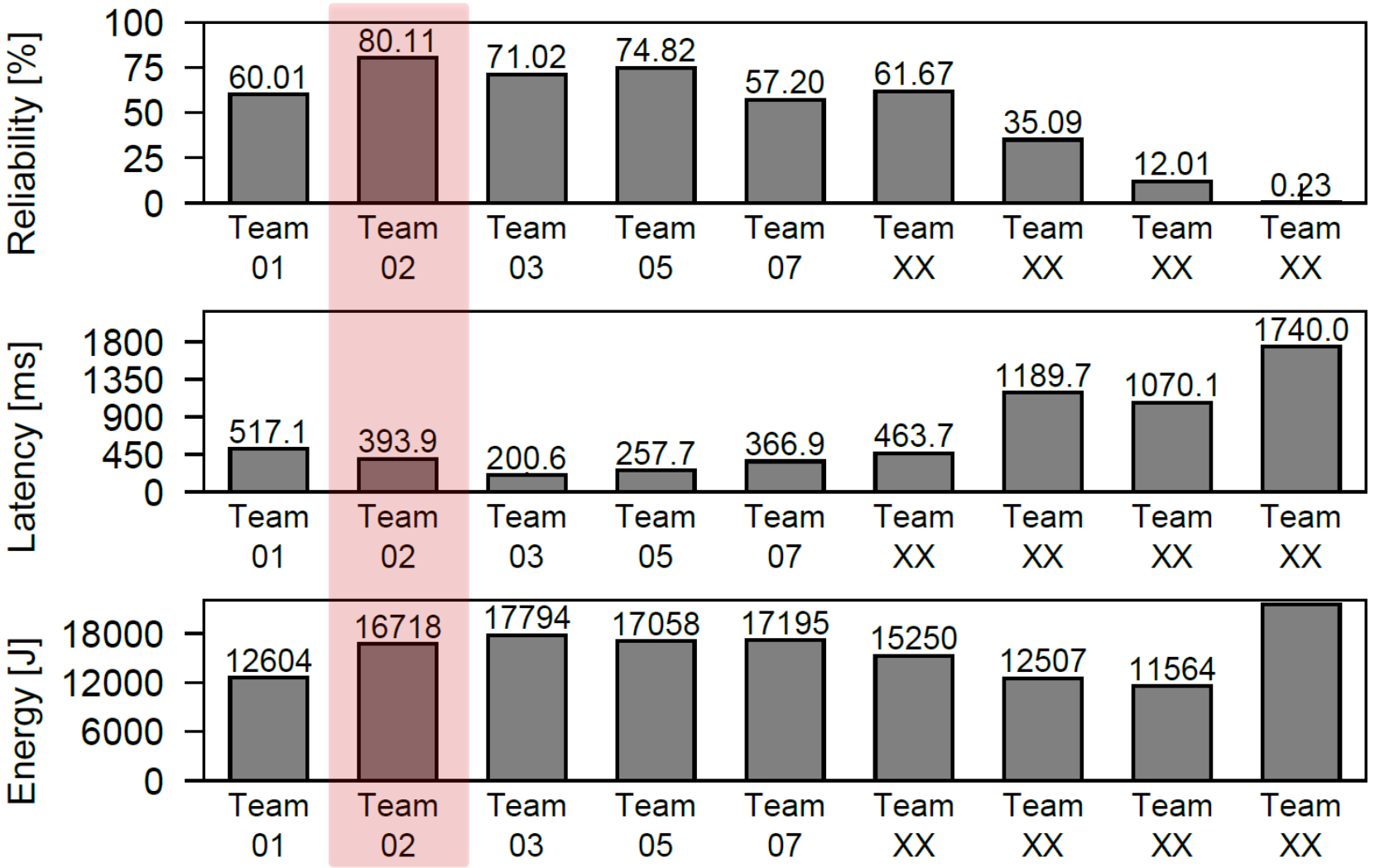
Scenario 6: Varying Interference

- Bursts of varying duration, dynamic channel for all jammers



Scenario 7: Varying Interference

- Bursts of varying duration, dynamic channel for all jammers

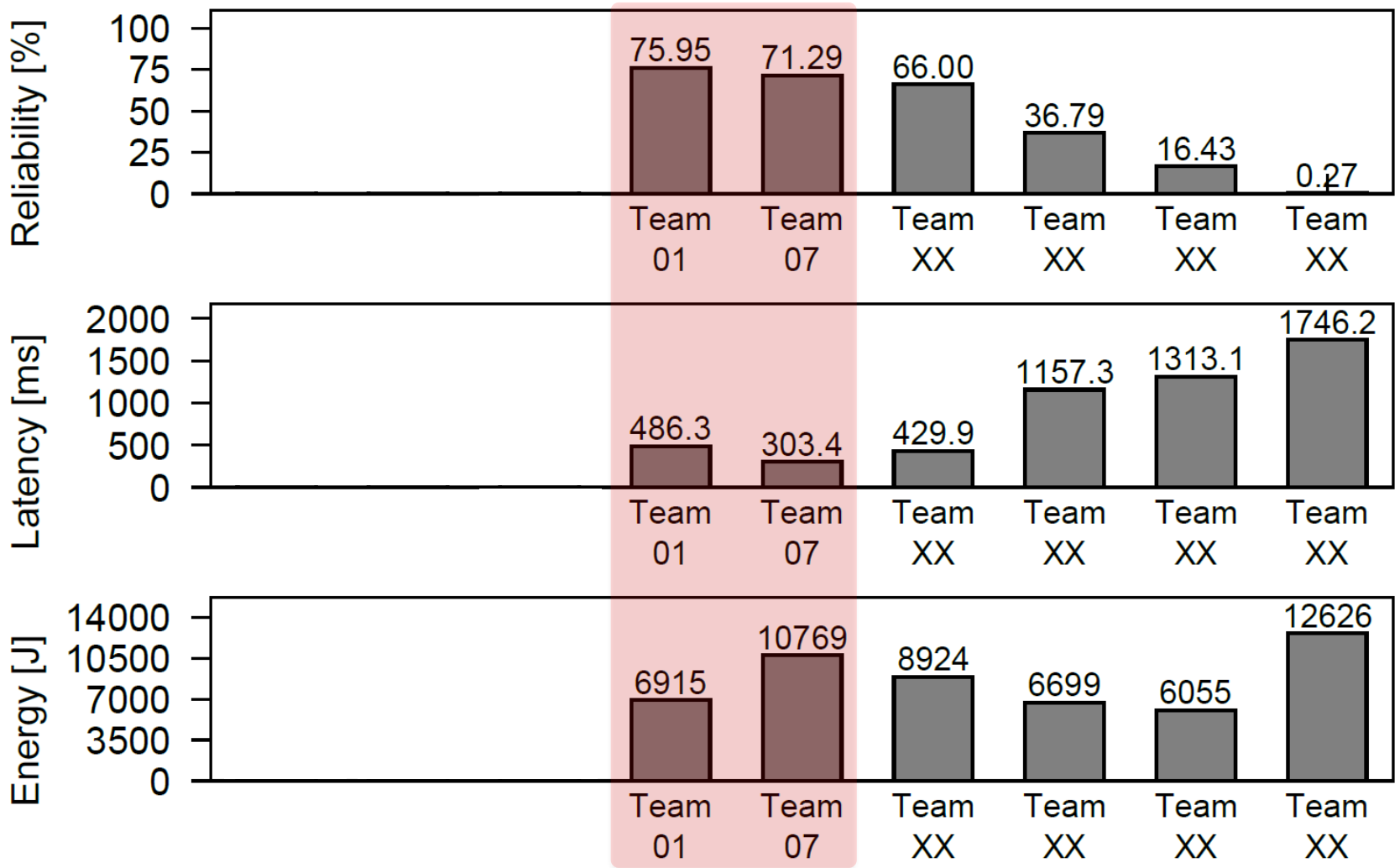


- **Team #01** – "Aggressive Synchronous Transmissions with In-network Processing for Dependable All-to-All Communication"

B. Al Nahas and O. Landsiedel
Chalmers University of Technology, Sweden

- **Team #07** – "Wireless-Transparent Sensing Platform"

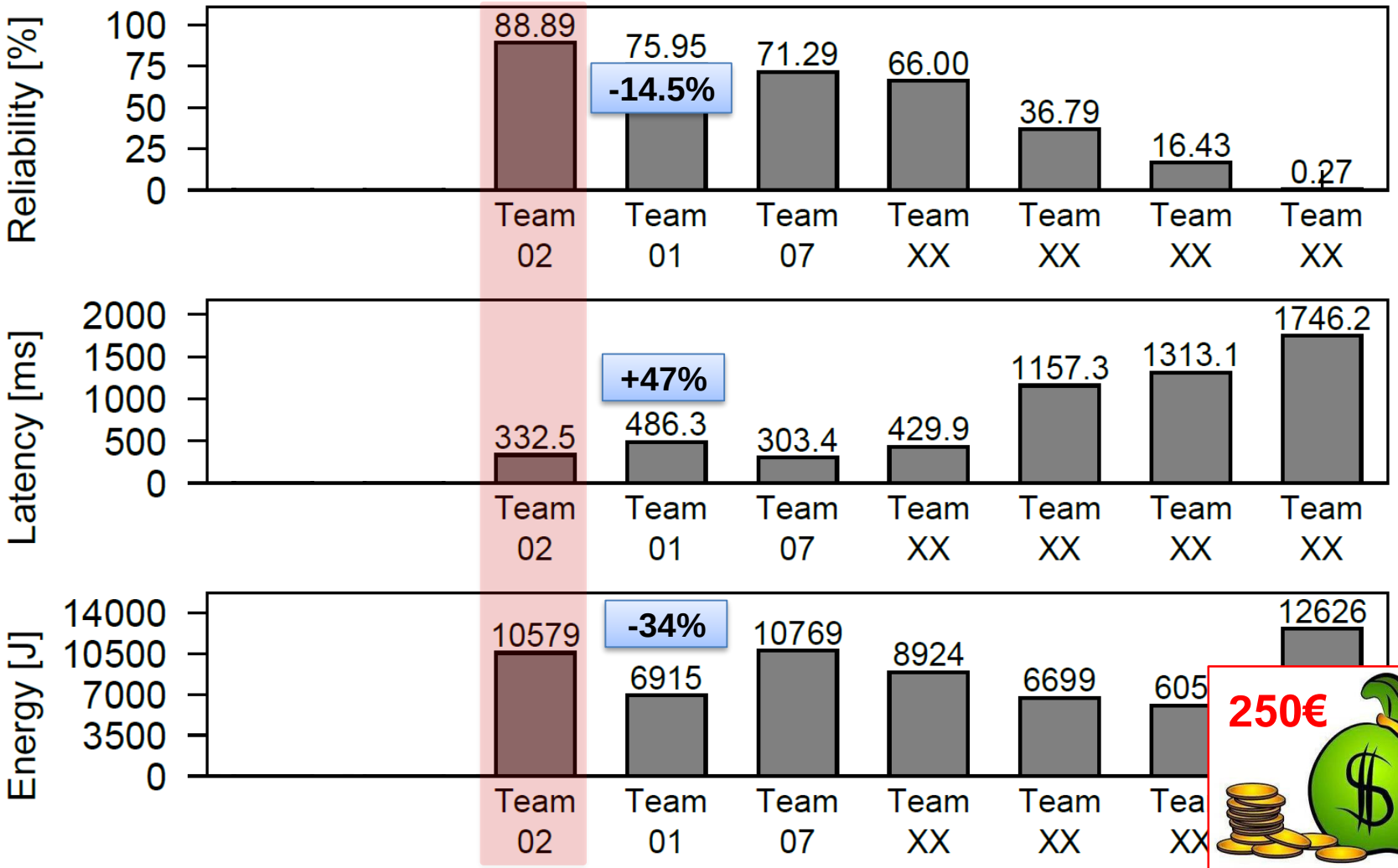
C. Liao, T. Sakdejayont, M. Suzuki, Y. Narusue, and H. Morikawa
School of Engineering, The University of Tokyo, Japan



3rd place: Team #02 – Using Enhanced OFPCOIN to Monitor Multiple Concurrent Events under Adverse Conditions

X. Ma[1,3], P. Zhang[4], W. Tang[1,3], X. Li[1,2], W. He[1,2,3], F. Zhang[1], J. Wei[1], and O. Theel[4]

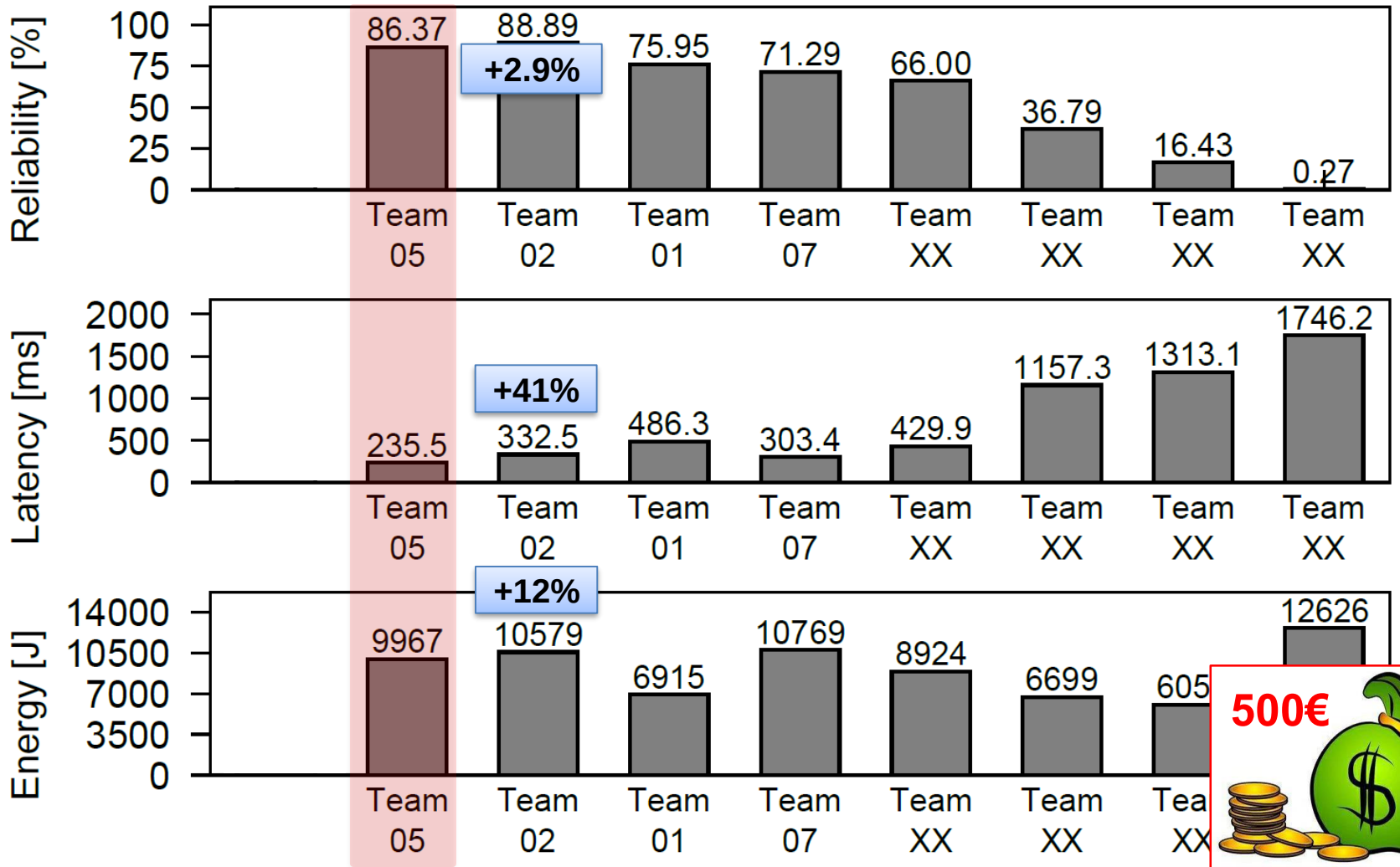
[1]Shanghai Advanced Research Institute, Chinese Academy of Sciences, China
[2]ShanghaiTech University, School of Information Science & Technology, China
[3]University of Chinese Academy of Sciences, China
[4]Carl von Ossietzky University of Oldenburg, Germany



- 2nd place: Team #05 – "CRYSTAL Clear: Making Interference Transparent"

M. Trobinger[1], T. Istomin[1,2], A.L. Murphy[2], and G.P. Picco[1]

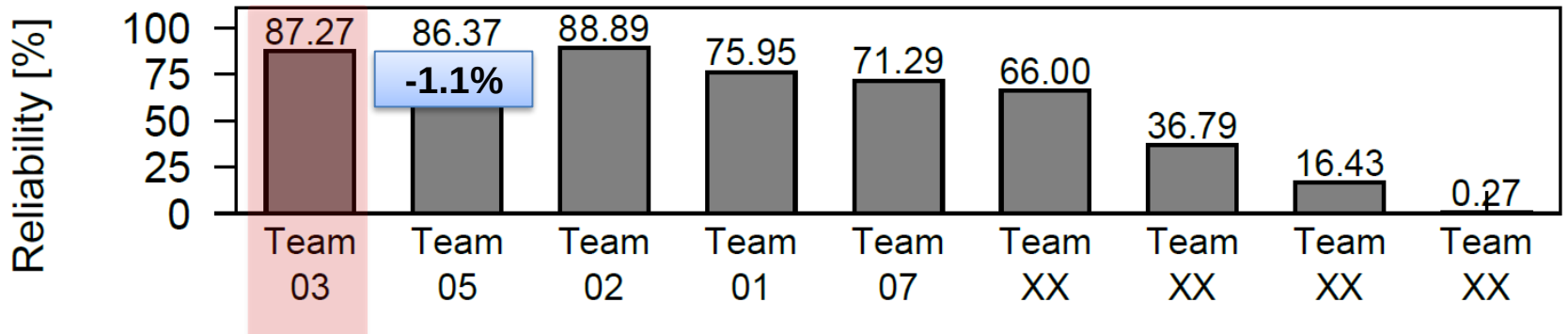
[1]University of Trento, Italy [2]Bruno Kessler Foundation, Italy

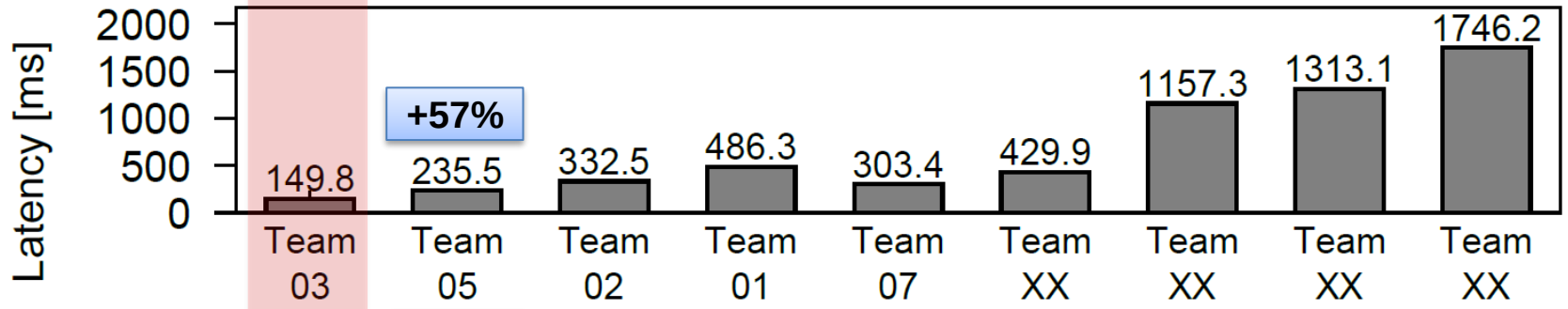


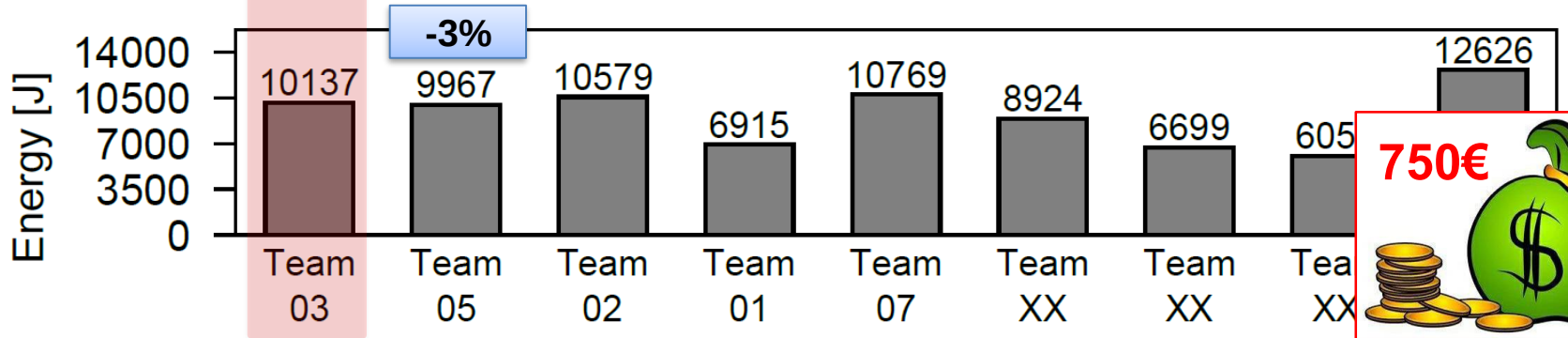
▪ 1st place: Team #03 – "BigBangBus"

A. Escobar[1,2], F. Moreno[1], B. Saez[1], A.J. Cabrera[1], J. Garcia-Jimenez[3], F.J. Cruz[4], U. Ruiz[4], A. Corona[5], J. Klaue[5], and D. Tati[5]

[1]Infineon Technologies AG, Germany
[2]RWTH Aachen University, Germany
[3]BMW AG, Germany
[4]eesy-innovation GmbH, Germany
[5]Airbus Group Innovations, Germany







Congratulations to This Year's Winners!

- 1st place: Team #03 – "BigBangBus"

A. Escobar[1,2], F. Moreno[1], B. Saez[1], A.J. Cabrera[1], J. Garcia-Jimenez[3], F.J. Cruz[4], U. Ruiz[4], A. Corona[5], J. Klaue[5], and D. Tati[5]

[1]Infineon Technologies AG, Germany
[2]RWTH Aachen University, Germany
[3]BMW AG, Germany
[4]eesy-innovation GmbH, Germany
[5]Airbus Group Innovations, Germany

- 2nd place: Team #05 – "CRYSTAL Clear: Making Interference Transparent"

M. Trobinger[1], T. Istomin[1,2], A.L. Murphy[2], and G.P. Picco[1]

[1]University of Trento, Italy
[2]Bruno Kessler Foundation, Italy

- 3rd place: Team #02 – Using Enhanced OFPCOIN to Monitor Multiple Concurrent Events under Adverse Conditions

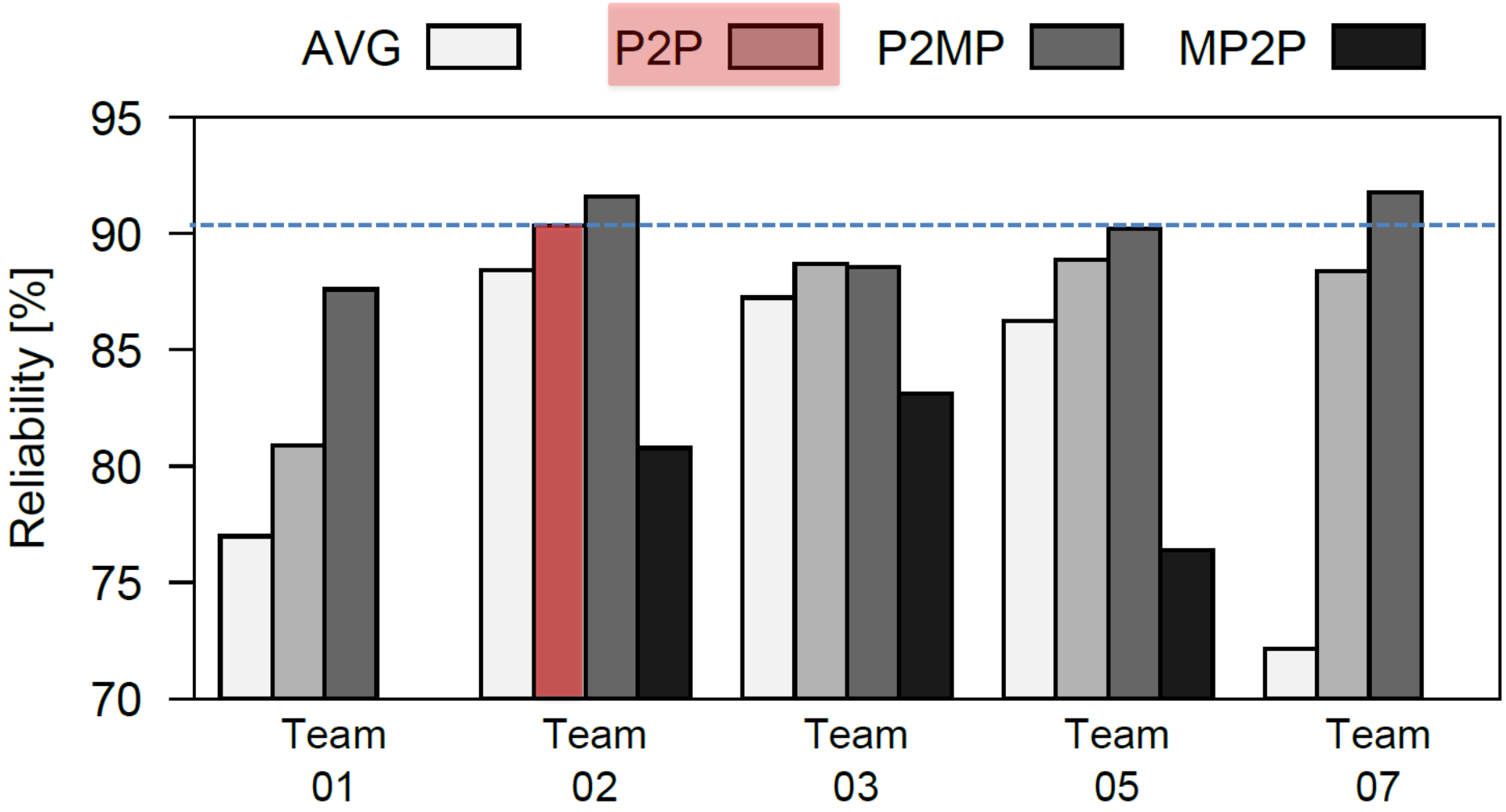
X. Ma[1,3], P. Zhang[4], W. Tang[1,3], X. Li[1,2], W. He[1,2,3], F. Zhang[1], J. Wei[1], and O. Theel[4]

[1]Shanghai Advanced Research Institute, Chinese Academy of Sciences, China
[2]ShanghaiTech University, School of Information Science & Technology, China
[3]University of Chinese Academy of Sciences, China
[4]Carl von Ossietzky University of Oldenburg, Germany

Aftermath

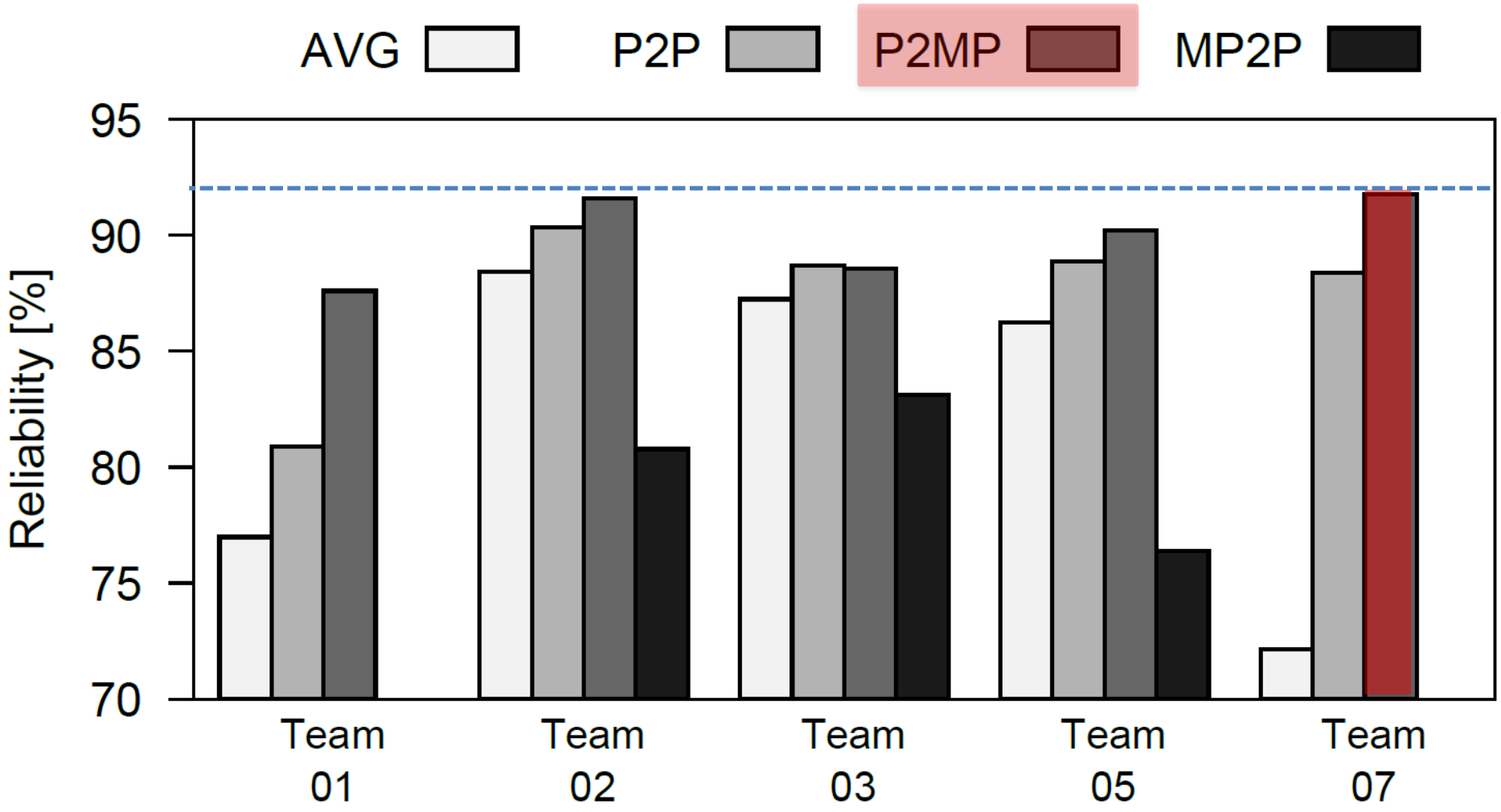
Aftermath

- Performance in Individual Scenarios



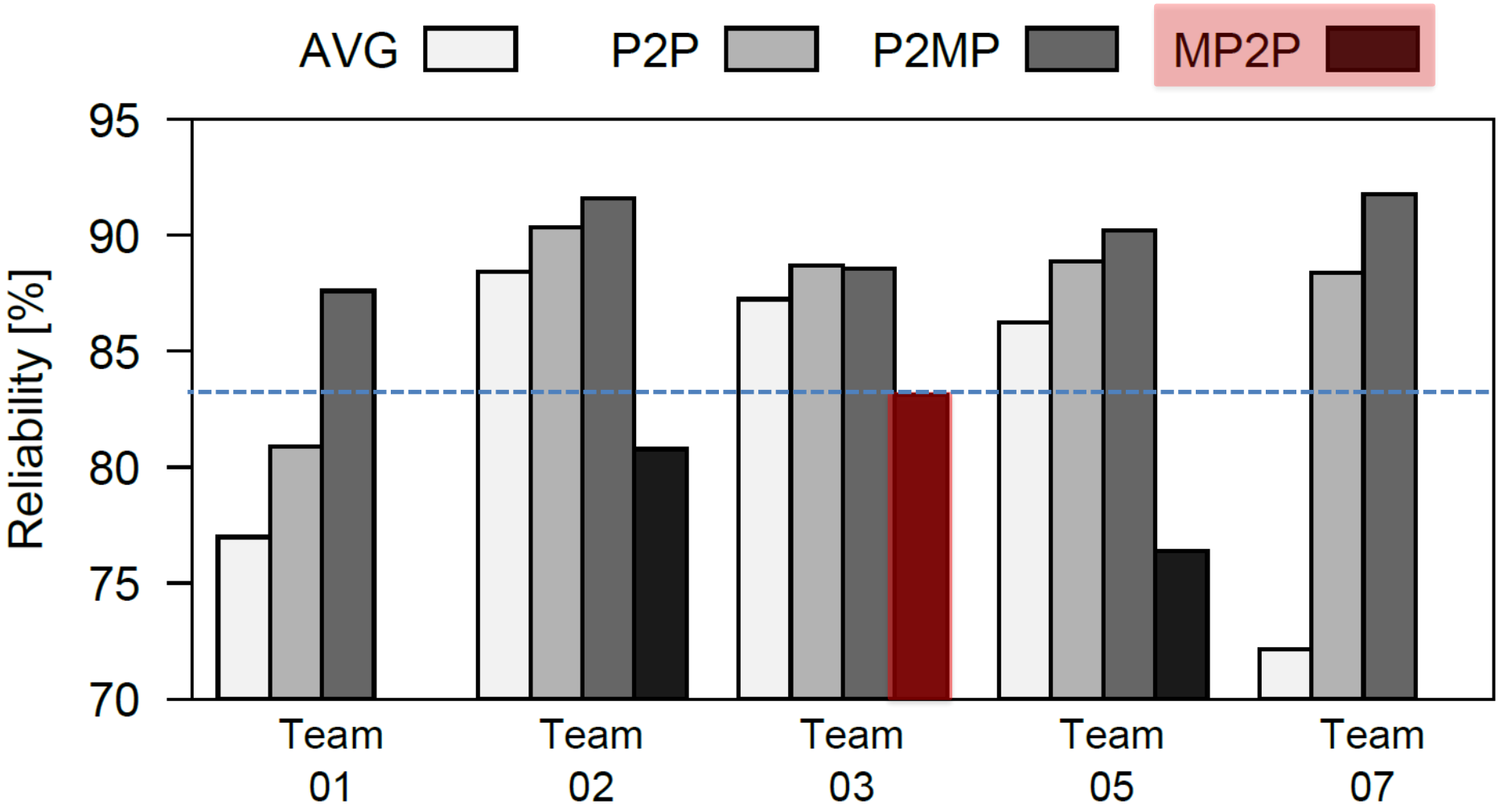
Aftermath

- Performance in Individual Scenarios



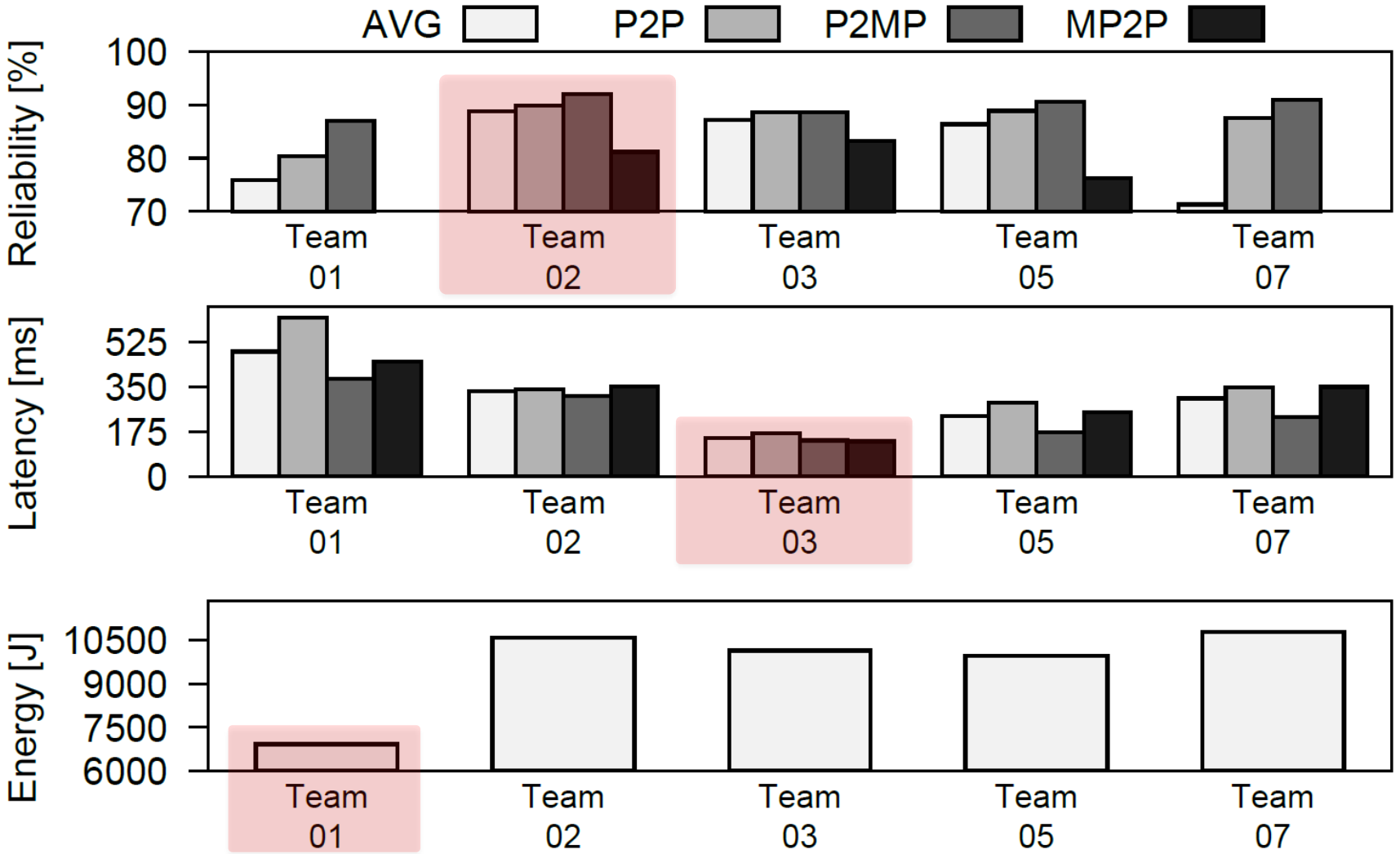
Aftermath

- Performance in Individual Scenarios



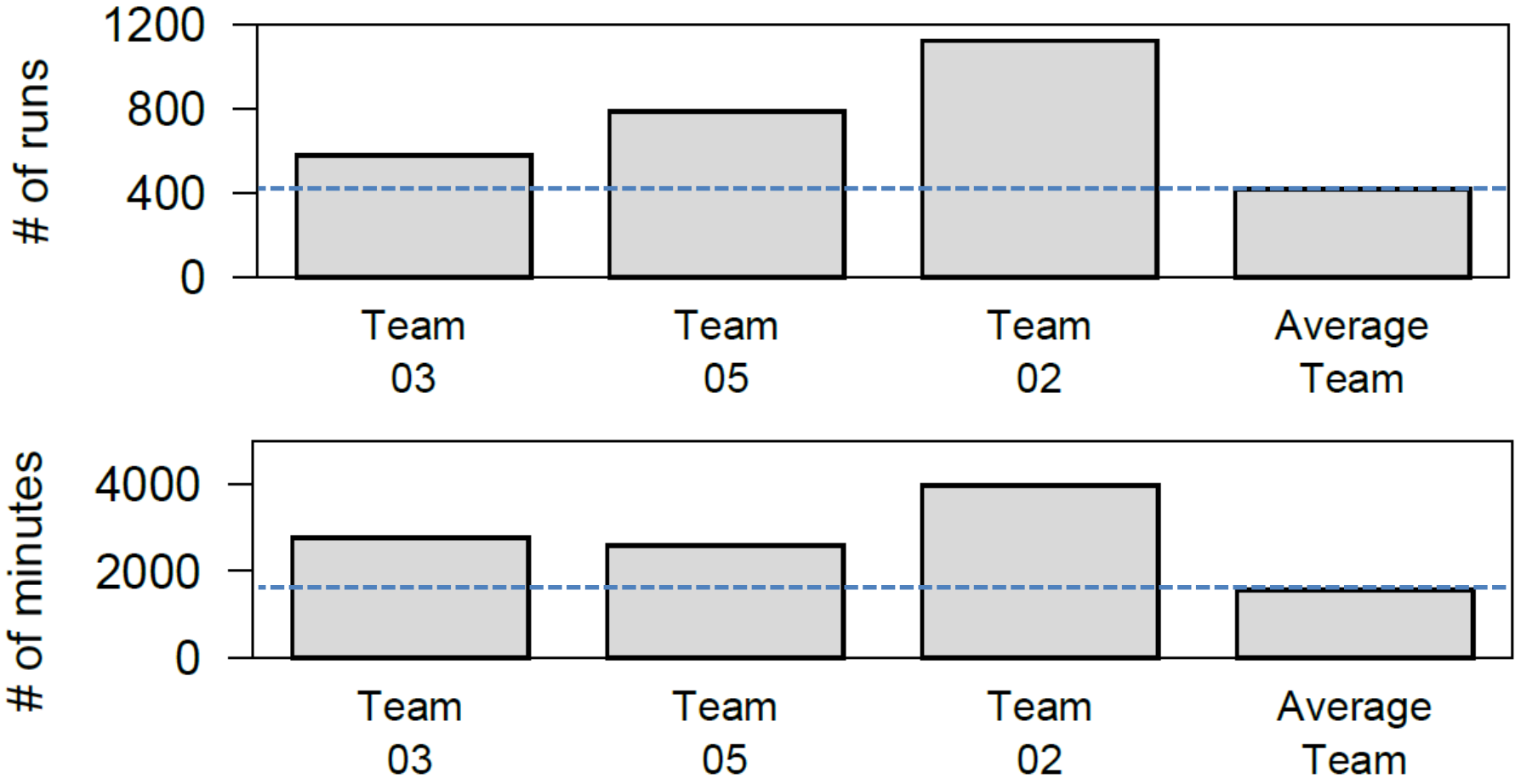
Aftermath

- Performance in Individual Scenarios



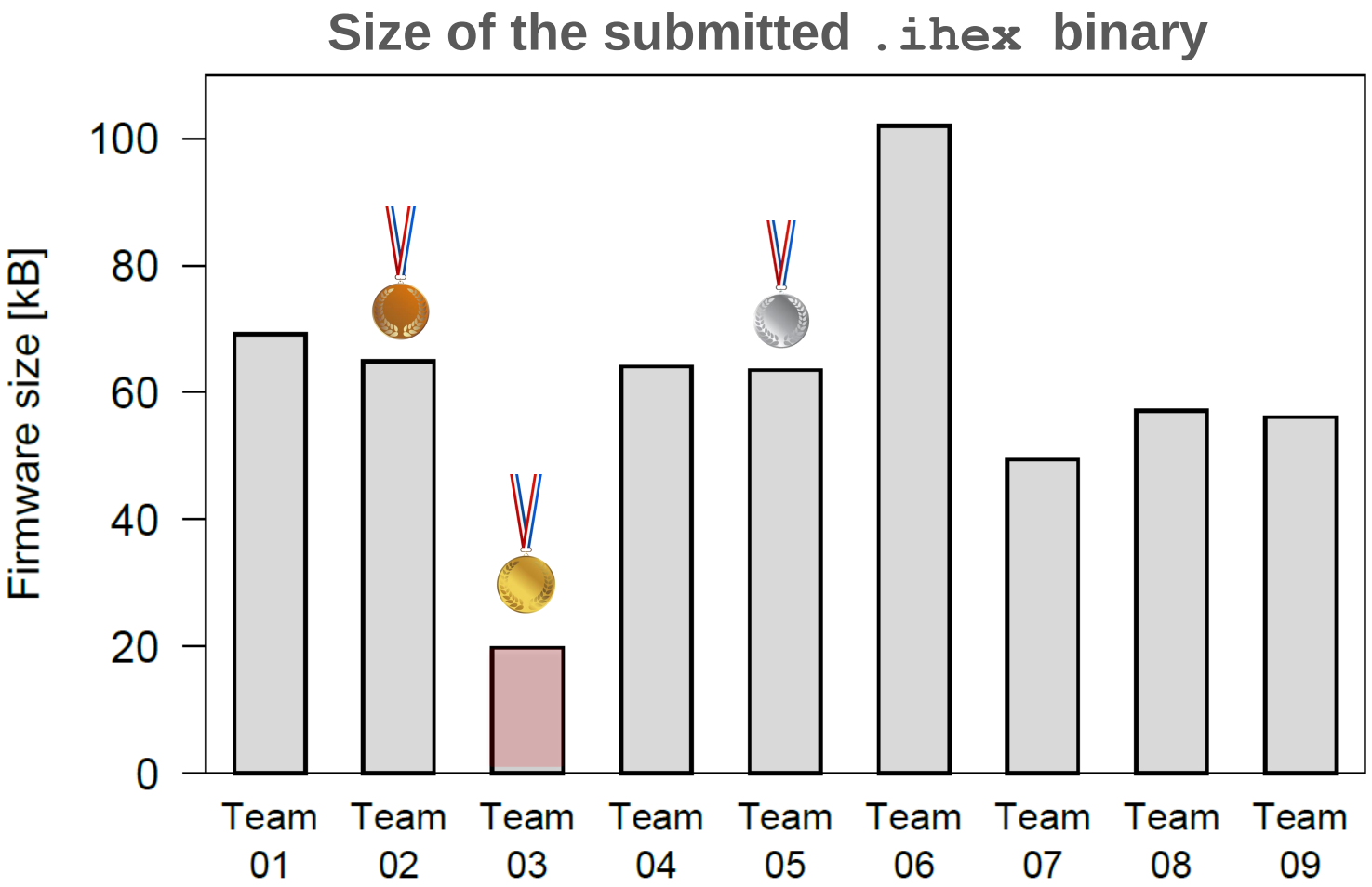
Aftermath

- Test, test, test!
  (Overall, 3765 runs and ~14.000 minutes of experimentation)



Aftermath

- Keep it simple & small?



Acknowledgments

- Thanks to everyone supporting this year's EWSN dependability competition!
  - The two co-chairs **Markus Schuss** and **Pablo Serrano**
  - Manuel Weber, Engelbert Meissl, and Oliver Bock for their help in setting up the competition infrastructure

- Thanks to our sponsors for financing the set-up of the competition infrastructure and the cash awards!