1KT: A Low-Cost 1000-Node Low-Power Wireless IoT Testbed

Mateusz Banaszek, Wojciech Dubiel, Jacek Łysiak, Maciej Dębski, Maciej Kisiel, Dawid Łazarczyk, Ewa Głogowska, Przemysław Gumienny, Cezary Siłuszyk, Piotr Ciołkosz, Agnieszka Paszkowska, Inga Rüb, Maciej Matraszek, Szymon Acedański, Przemysław Horban, Konrad Iwanicki

University of Warsaw

MSWiM 2021, Alicante, Spain, November 24, 2021

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“What is 1KT?”

1KT is a new testbed

1KT is a new testbed

- Internet of Things IoT

1KT is a new testbed

- Internet of Things

- low-power wireless

1KT is a new testbed

- Internet of Things IoT

- low-power wireless IEEE 802.15.4
  Bluetooth Low Energy (BLE)

1KT is a new testbed

- Internet of Things IoT

- low-power wireless IEEE 802.15.4
  Bluetooth Low Energy (BLE)

- large smart-building

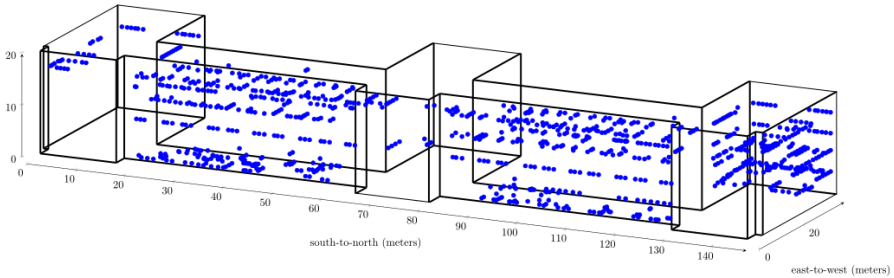
1KT is a new testbed

- Internet of Things IoT

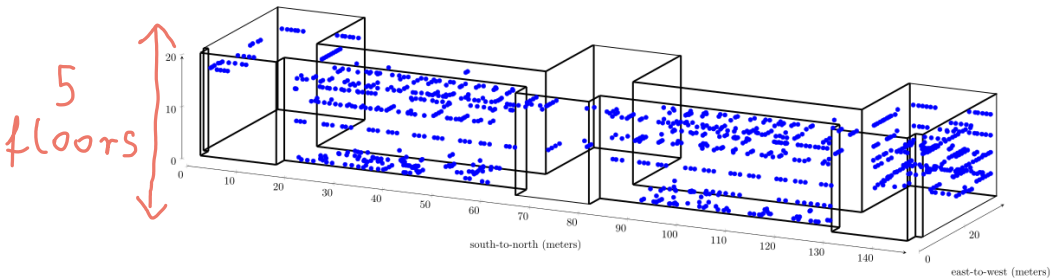
- low-power wireless IEEE 802.15.4
  Bluetooth Low Energy (BLE)

- large smart-building 1000 devices
  single indoor site

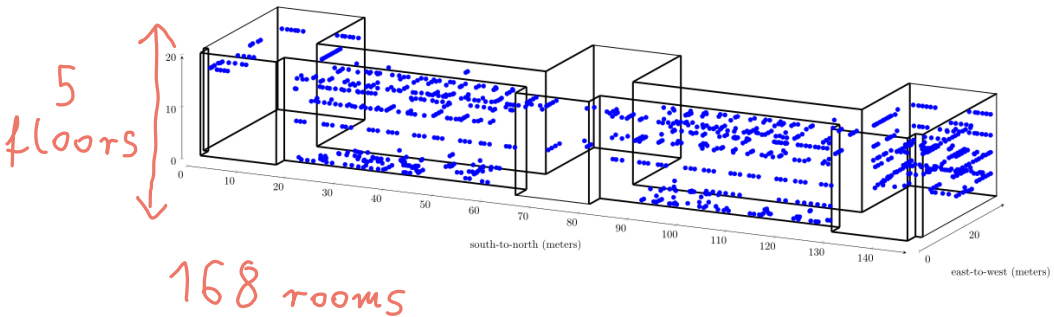
950 devices...


20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
south-to-north (meters)
0
20
east-to-west (meters)

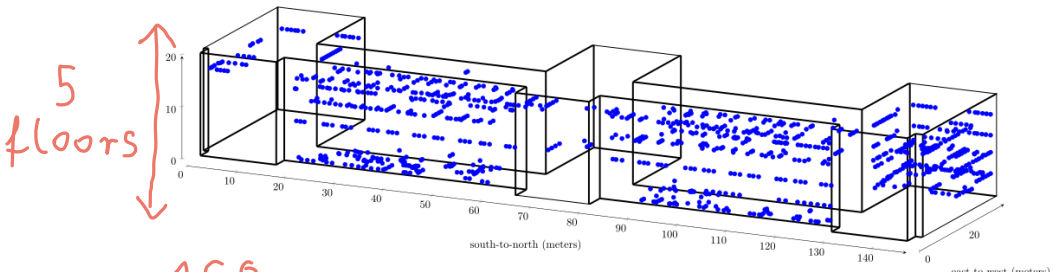
950 devices...


5
floors
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
south-to-north (meters)
0
20
east-to-west (meters)

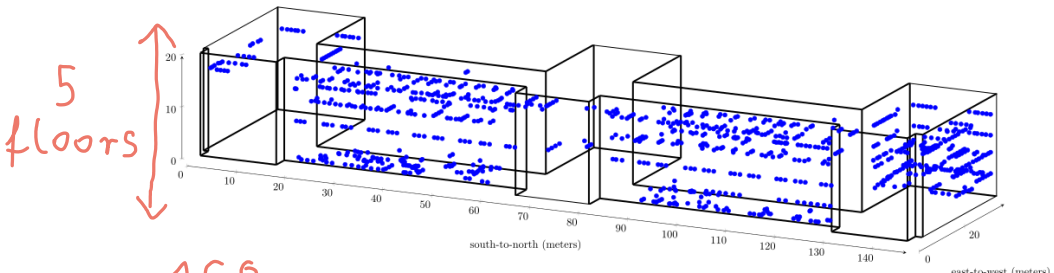
950 devices...



950 devices...


5
floors
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
south-to-north (meters)
0
20
east-to-west (meters)
168 rooms
offices

950 devices...

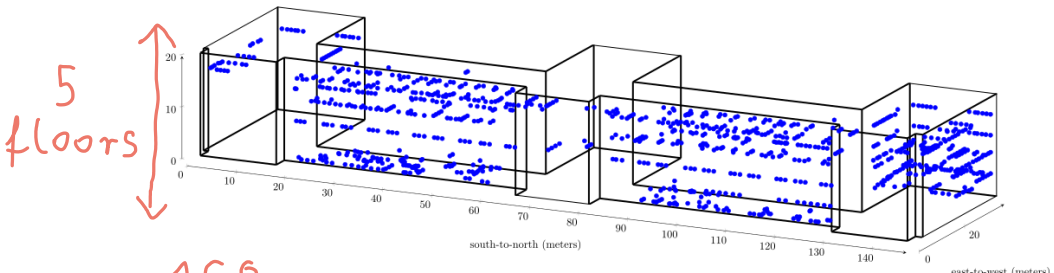


168 rooms

offices

computer labs

950 devices...



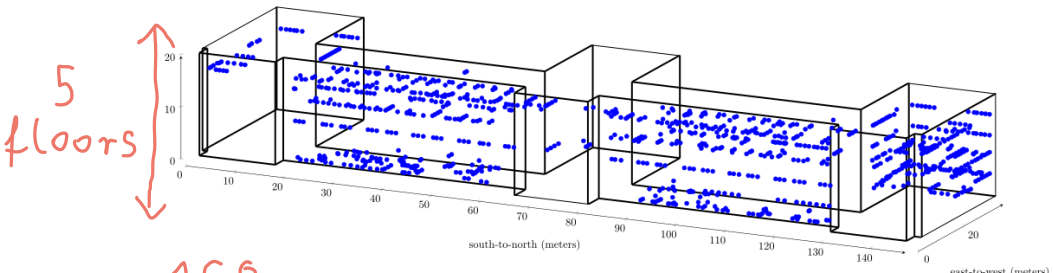
168 rooms

offices

lecture rooms

computer labs

950 devices...



168 rooms

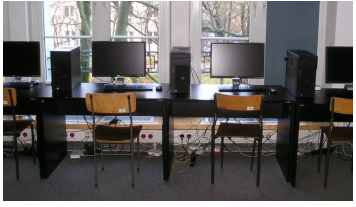
offices

lecture rooms

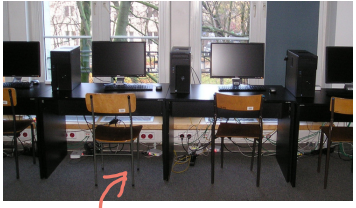
computer labs

shared spaces

...directly in human spaces

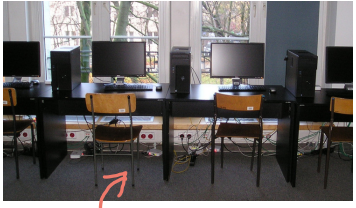


...directly in human spaces



under desks

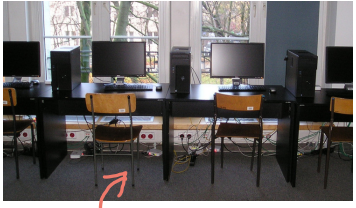
...directly in human spaces



under desks

on file cabinets

...directly in human spaces

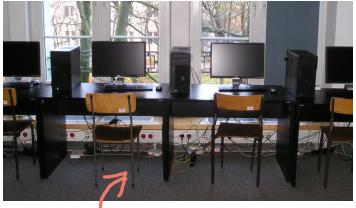


under desks

on file cabinets

on desks

...directly in human spaces



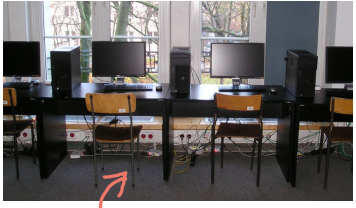
under desks

on file cabinets

on desks

behind desks

...directly in human spaces



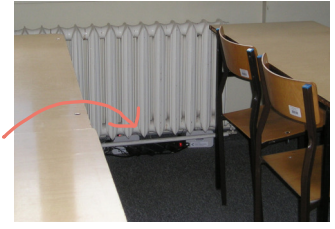
under desks

on file cabinets

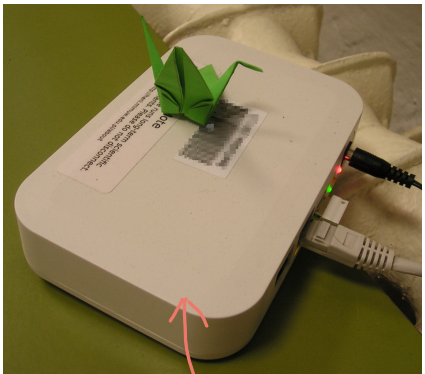
on desks

behind desks

next to desks



...directly in human spaces



origami showcase

50 devices

50 devices

development

50 devices

development

preliminary testing

50 devices

development

preliminary testing

small-scale experimentation

50 devices

development

preliminary testing

small-scale experimentation

maintenance

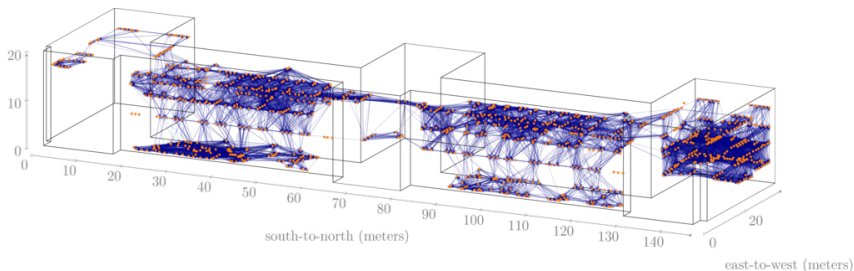
“What is the wireless network of 1KT like?”

Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

Wireless characteristic

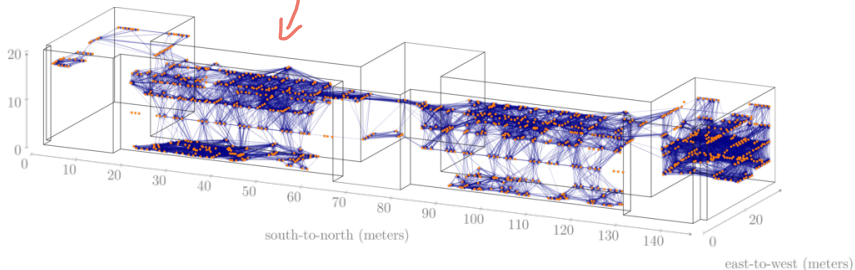
7 days, IEEE 802.15.4, -3 dBm



Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

over 60,000 links

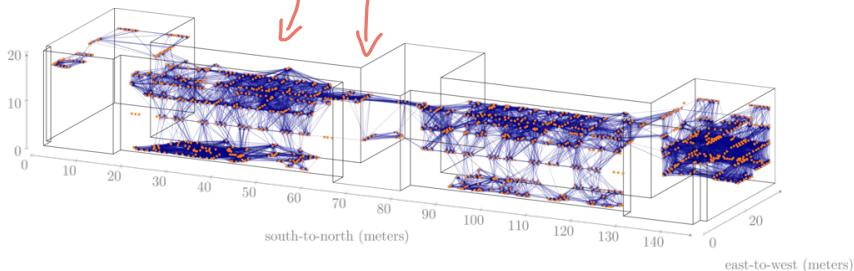


Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

over 60,000 links

up to 50 meters

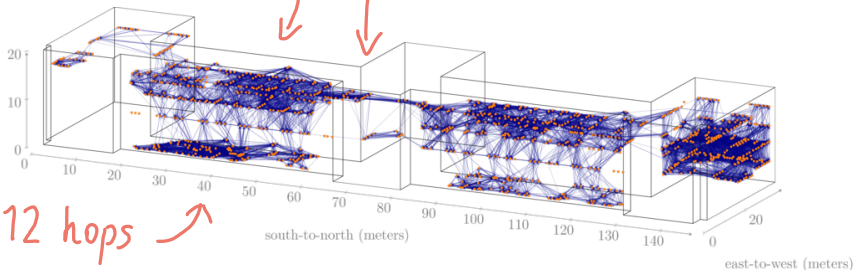


Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

over 60,000 links

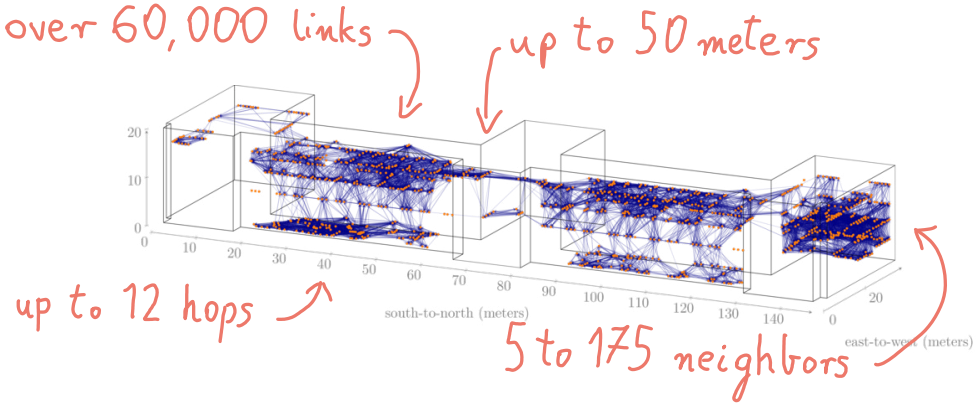
up to 50 meters



up to 12 hops

Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm



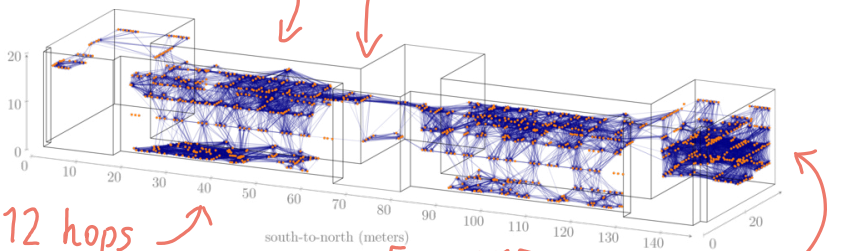
Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

PRR > 0%

over 60,000 links

up to 50 meters



up to 12 hops

5 to 175 neighbors

Wireless characteristic

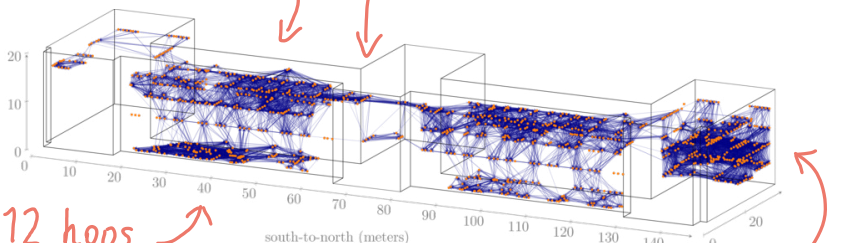
7 days, IEEE 802.15.4, -3 dBm

PRR > 0%

PRR ≥ 90%

over 60,000 links

up to 50 meters



up to 12 hops

5 to 175 neighbors

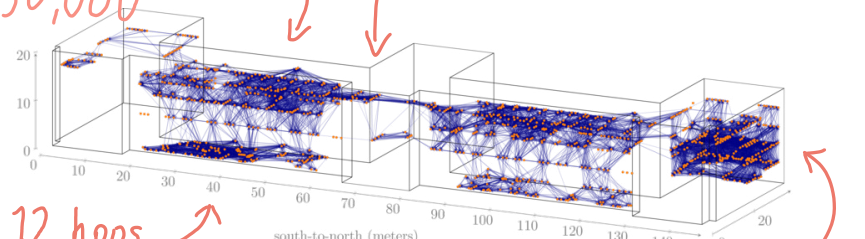
Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

PRR > 0%
PRR ≥ 90%

over 60,000 links
30,000

up to 50 meters



up to 12 hops

5 to 175 neighbors

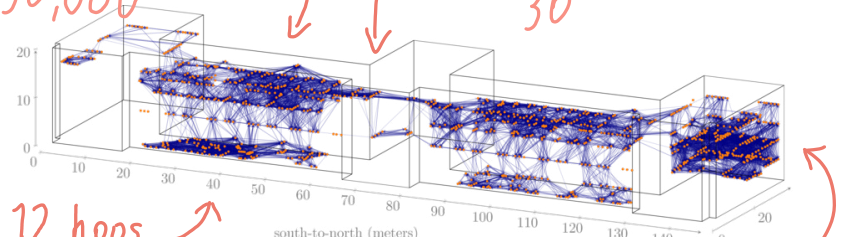
Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

PRR > 0%
PRR ≥ 90%

over 60,000 links
30,000

up to 50 meters
30



up to 12 hops

5 to 175 neighbors

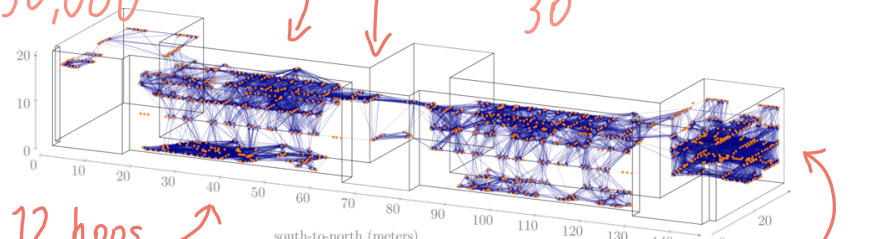
Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

PRR > 0%
PRR ≥ 90%

over 60,000 links
30,000

up to 50 meters
30



up to 12 hops
23

5 to 175 neighbors

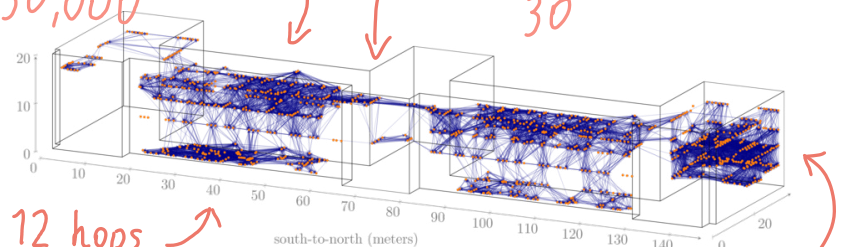
Wireless characteristic

7 days, IEEE 802.15.4, -3 dBm

PRR > 0%
PRR ≥ 90%

over 60,000 links
30,000

up to 50 meters
30



up to 12 hops
23

5 to 175 neighbors
1 to 120

“What about other testbeds?”

Other testbeds

	#devices	deployment	
IoT-LAB Grenoble	608	1 floor	floors & ceilings

Other testbeds

	#devices	deployment	
IoT-LAB Grenoble	608	1 floor	floors & ceilings
FlockLab 2	106 (30 spots)	1 floor & outdoor	human spaces

Other testbeds

	#devices	deployment	
IoT-LAB Grenoble	608	1 floor	floors & ceilings
FlockLab 2	106 (30 spots)	1 floor & outdoor	human spaces
Indriya2	58	3 floors	ceilings

Other testbeds

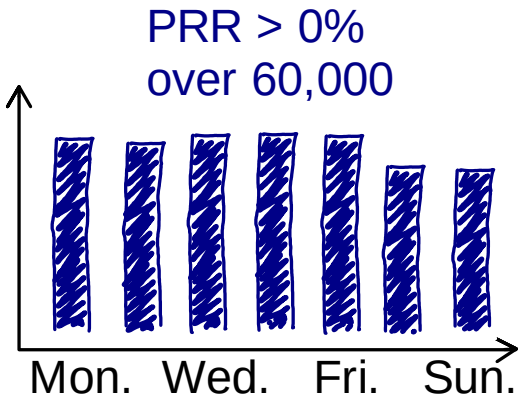
	#devices	deployment	
IoT-LAB Grenoble	608	1 floor	floors & ceilings
FlockLab 2	106 (30 spots)	1 floor & outdoor	human spaces
Indriya2	58	3 floors	ceilings
1KT	950+50	5 floors	human spaces

“Do we need more testbeds?”

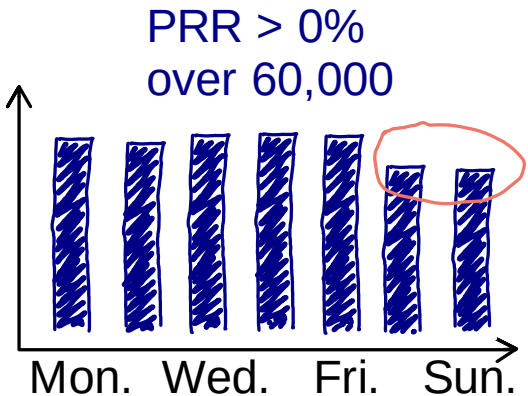
An example

PRR > 0%
over 60,000

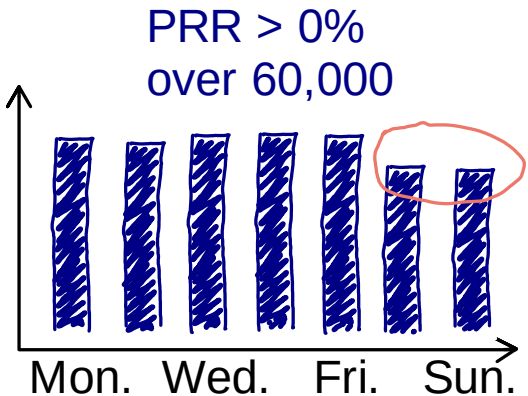
An example

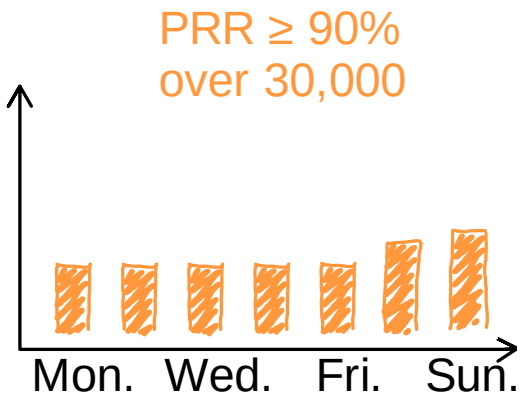


An example

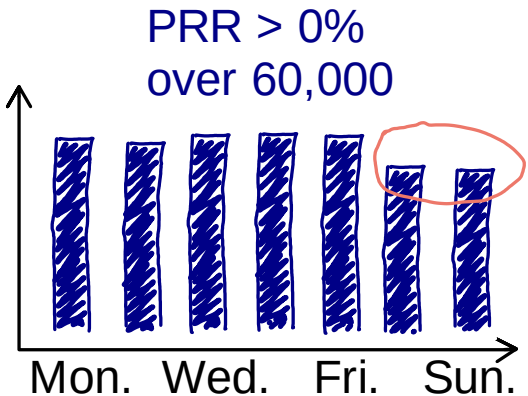


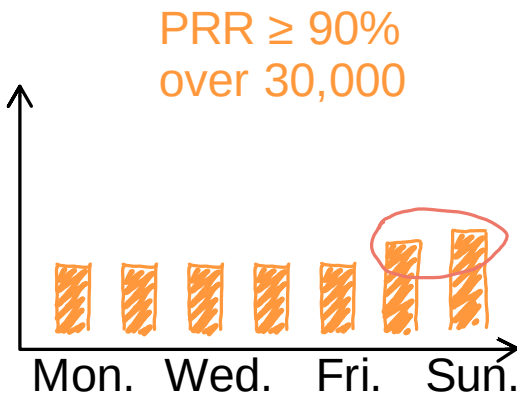
An example


PRR > 0%
over 60,000
Mon.
Wed.
Fri.
Sun.

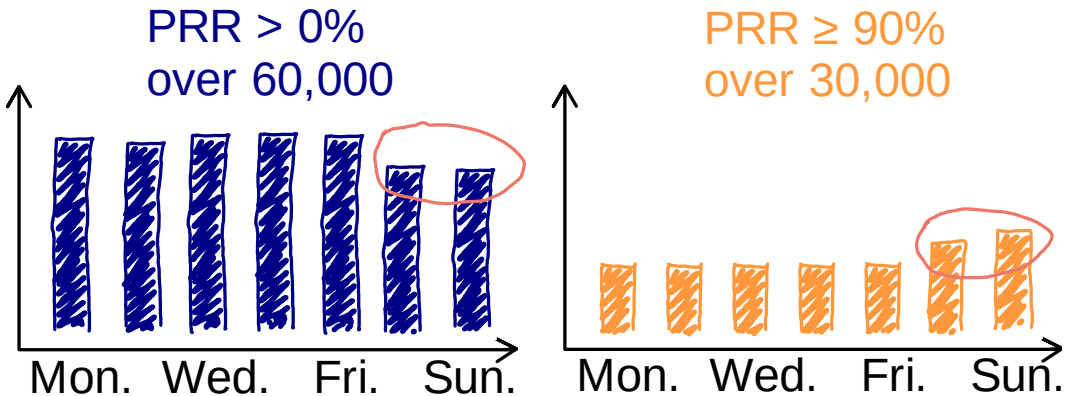

PRR ≥ 90%
over 30,000
Mon.
Wed.
Fri.
Sun.

An example


PRR > 0%
over 60,000
Mon.
Wed.
Fri.
Sun.

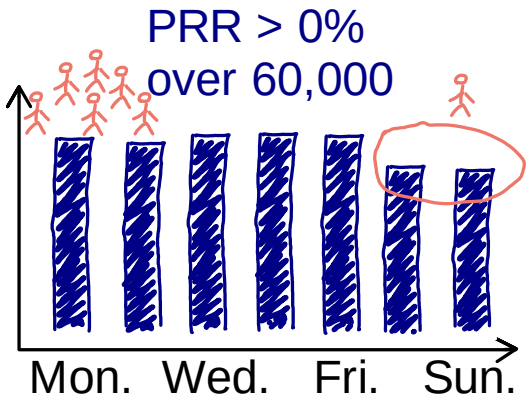

PRR ≥ 90%
over 30,000
Mon.
Wed.
Fri.
Sun.

An example



it is 「university」 building

An example



it is a 「university」 building

More testbeds are needed

More testbeds are needed

physical changes $\Rightarrow$ wireless changes

More testbeds are needed

physical changes ⇒ wireless changes

different environments

More testbeds are needed

physical changes ⇒ wireless changes

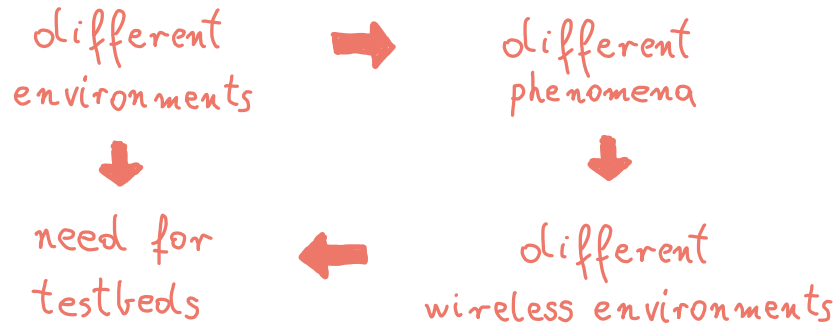
More testbeds are needed

physical changes ⇒ wireless changes

different environments → different phenomena → different wireless environments

More testbeds are needed

physical changes ⇒ wireless changes



“Did you have to design a new testbed?”

We need low-cost large-scale designs

large-scale testbeds are expensive

We need low-cost large-scale designs

large-scale testbeds are expensive

1000 x

IoT-LAB

FlockLab 2

. . .

=

We need low-cost large-scale designs

~~large-scale testbeds are expensive~~

1000 x

IoT-LAB

FlockLab 2

. . .

=

We need low-cost large-scale designs

~~large-scale testbeds are expensive~~

1000 x

IoT-LAB

FlockLab 2

. . .

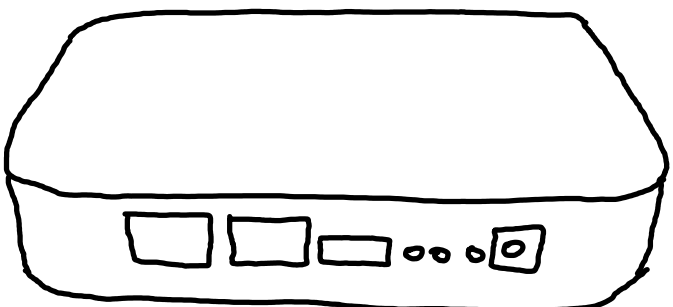
=

1KT: A Low-Cost 1000-Node Low-Power Wireless IoT Testbed

“How to design a low-cost large-scale testbed?”

Building blocks of 1KT

CherryMote:

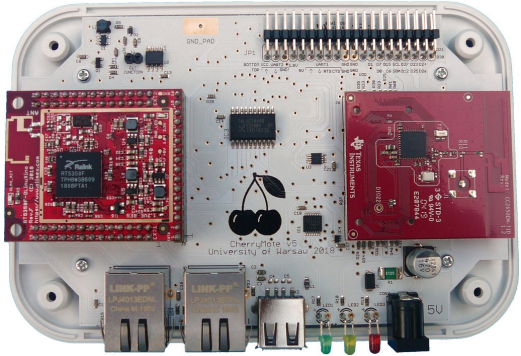


CherryMote outside

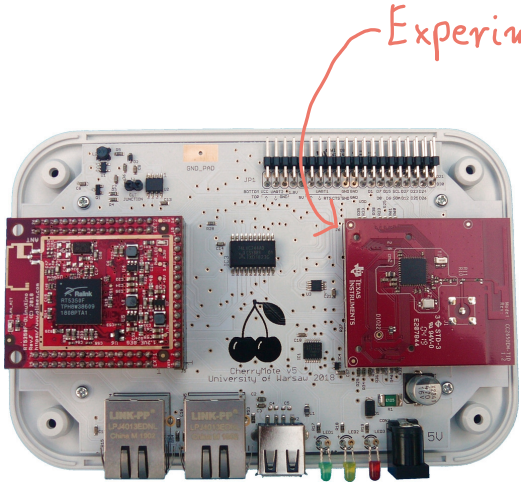
CherryMote outside

homogenous testbed ⇒ effects of scale

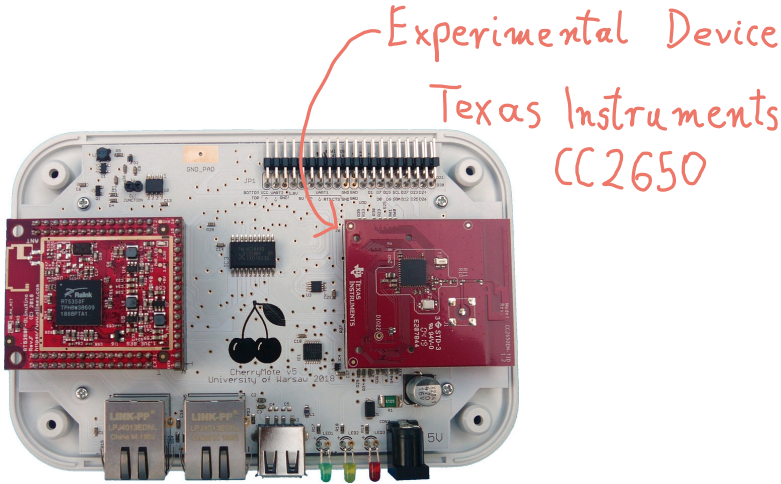
CherryMote inside



CherryMote inside



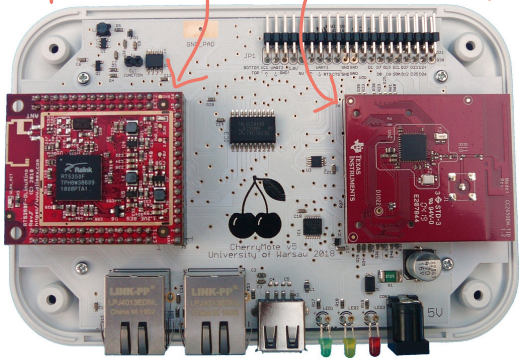
CherryMote inside



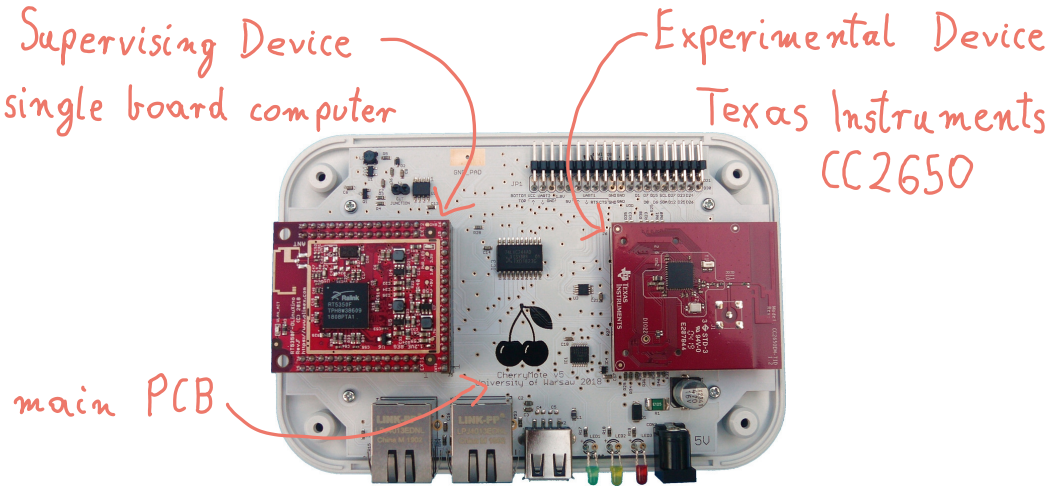
CherryMote inside

Supervising Device
single board computer

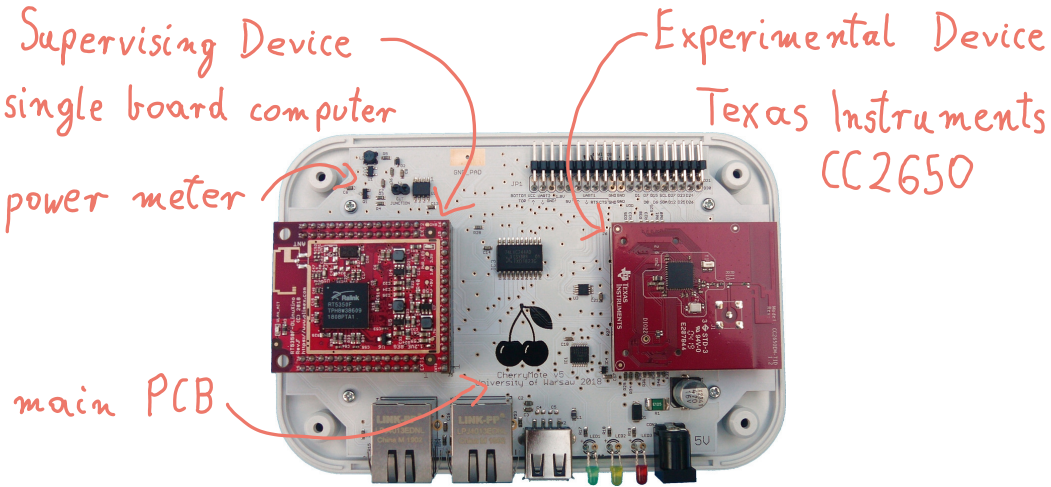
Experimental Device
Texas Instruments
CC2650



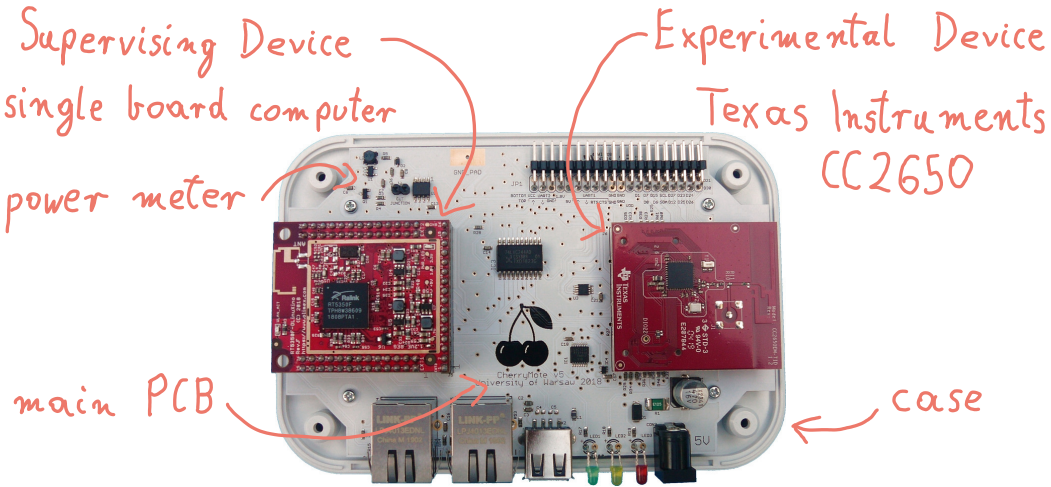
CherryMote inside



CherryMote inside



CherryMote inside



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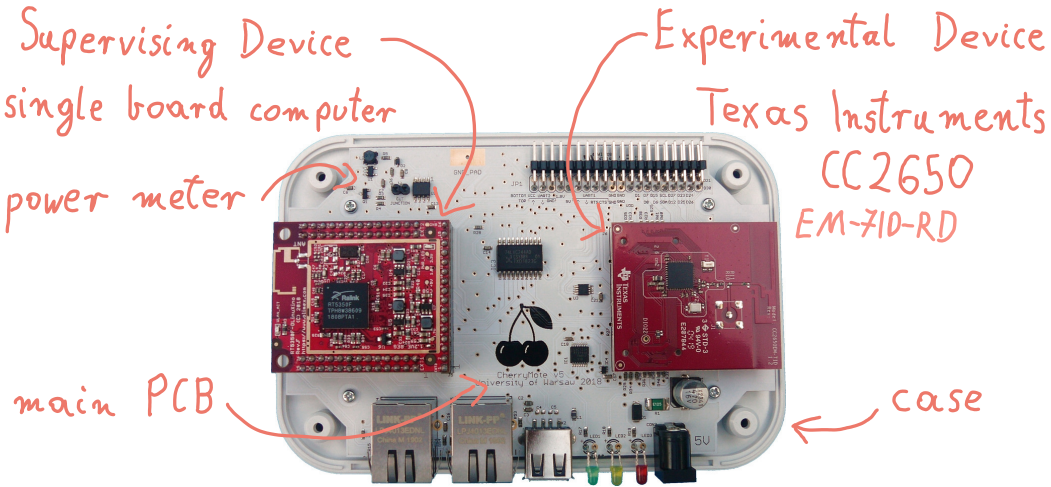

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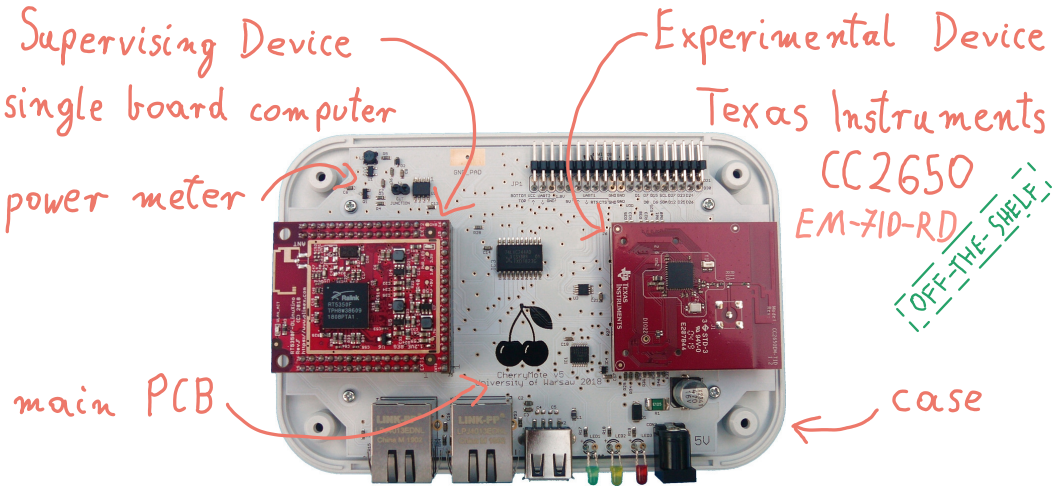

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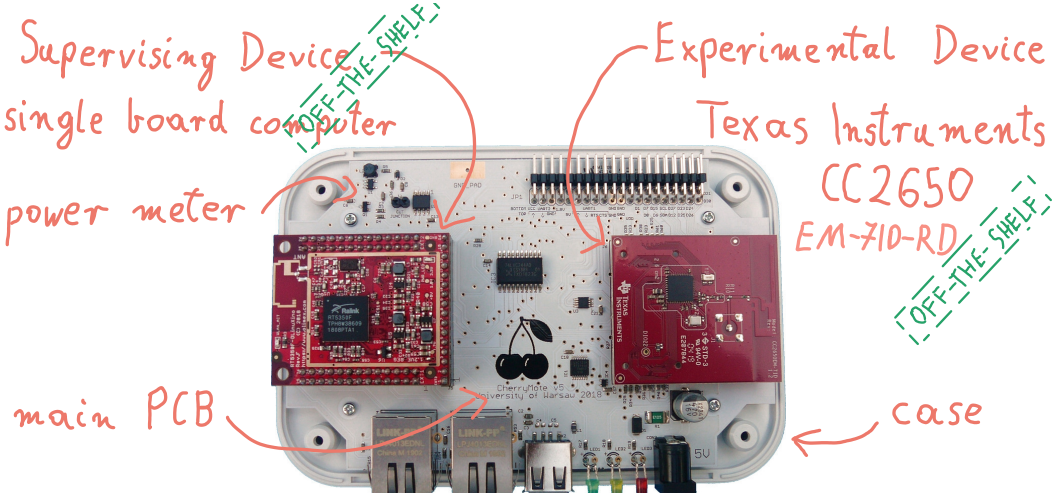

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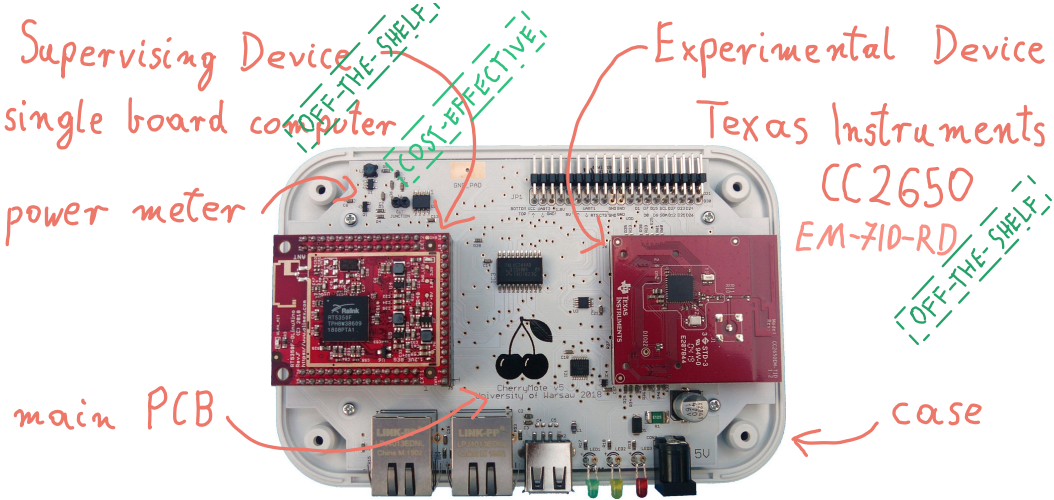

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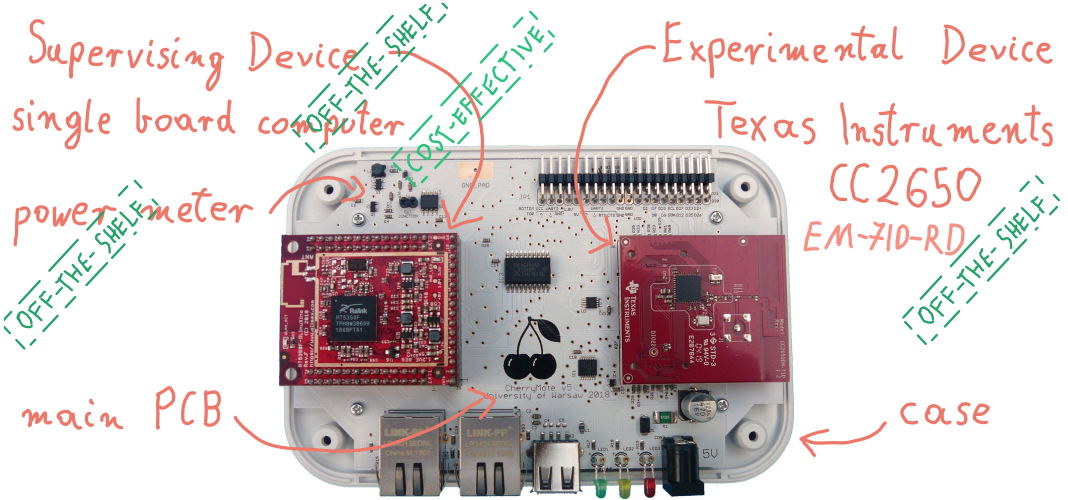

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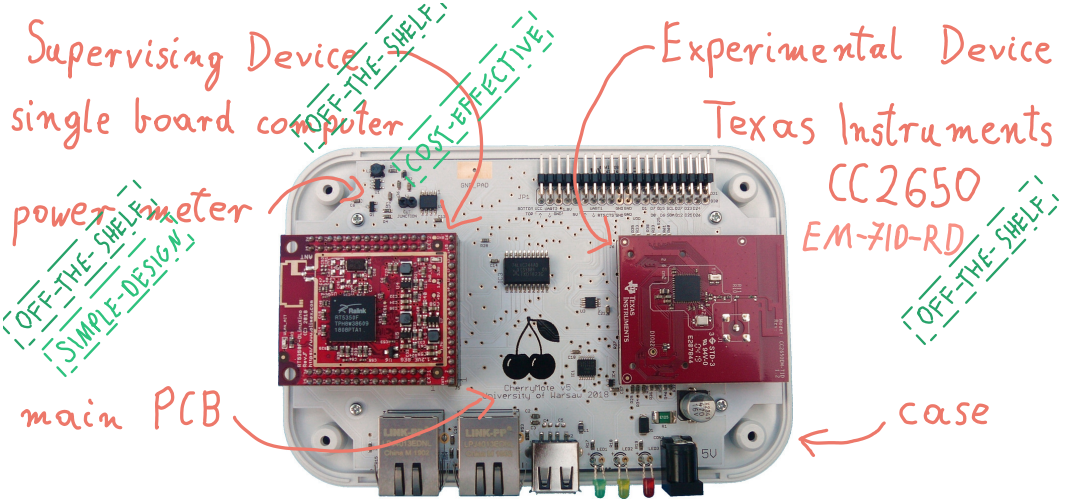

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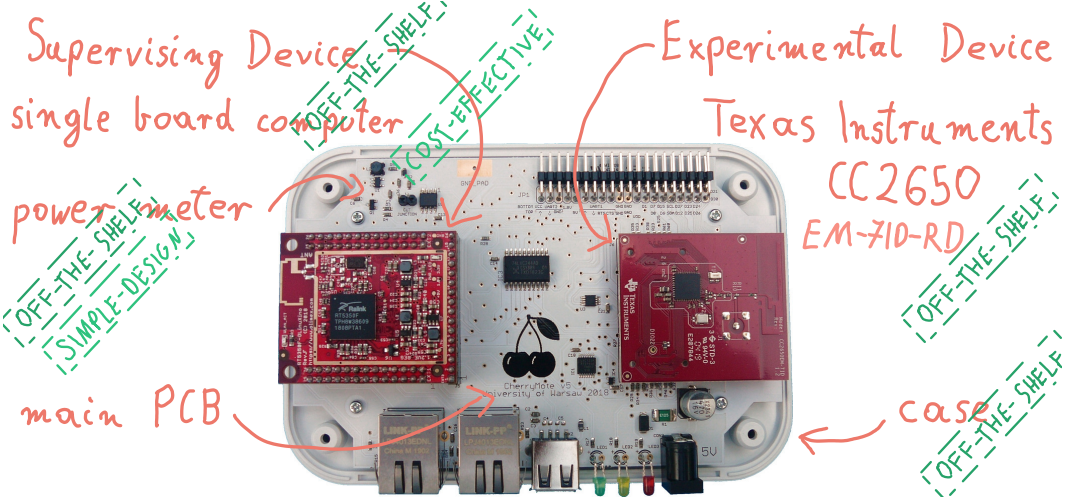

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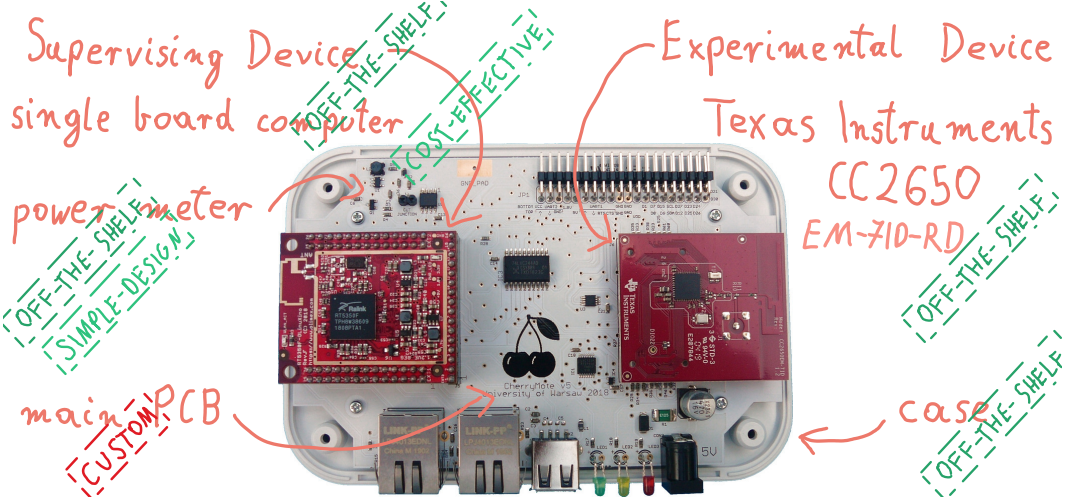
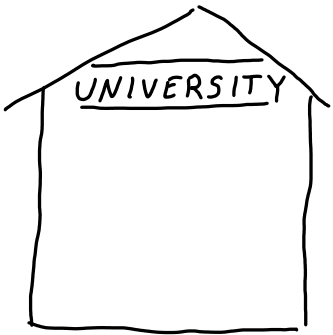
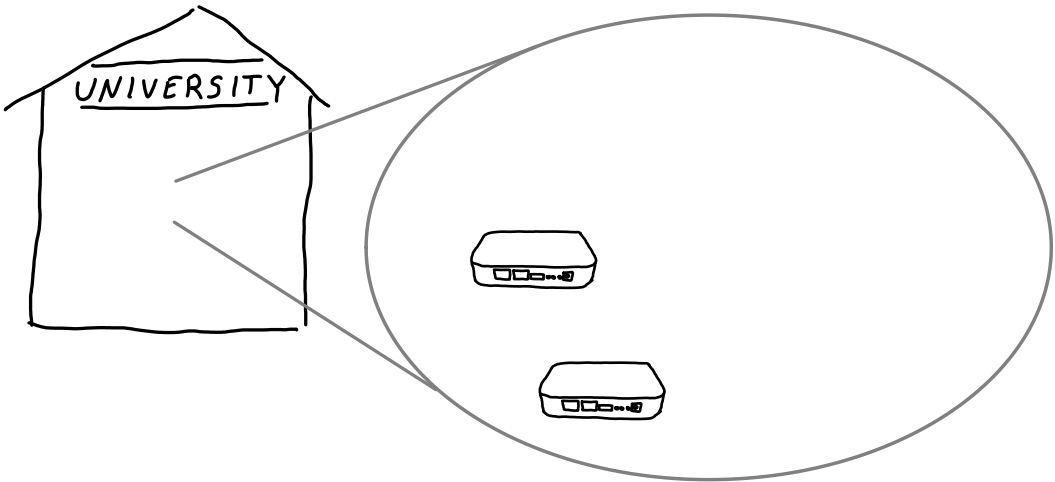


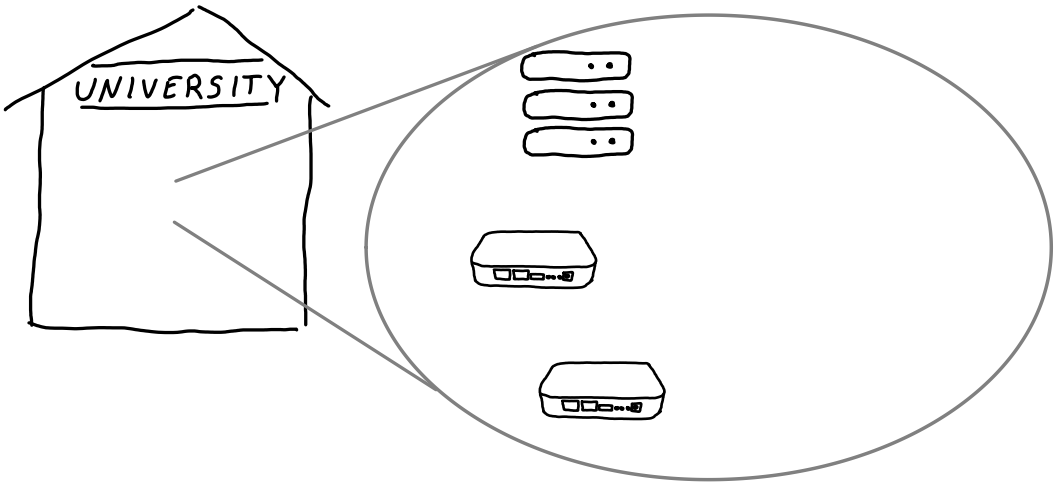
Design of the control network



Design of the control network



Design of the control network



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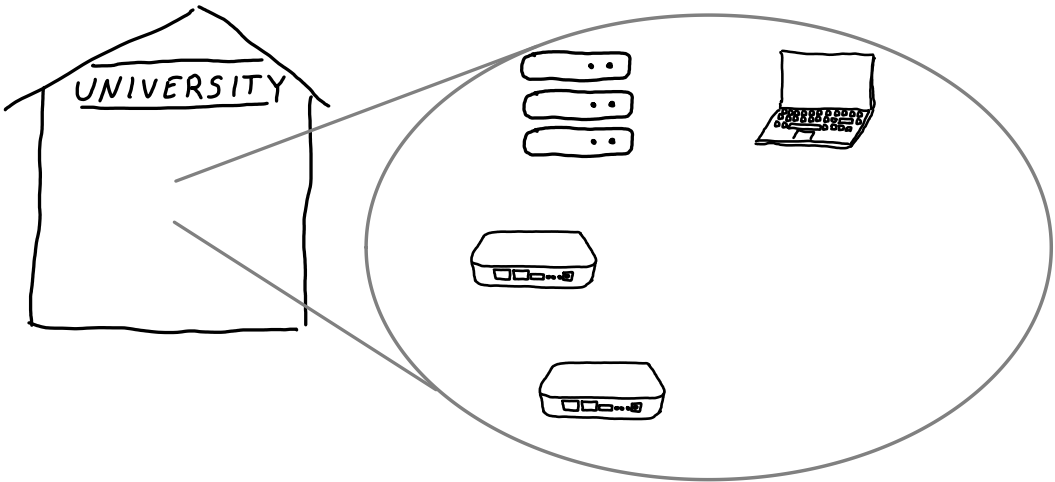

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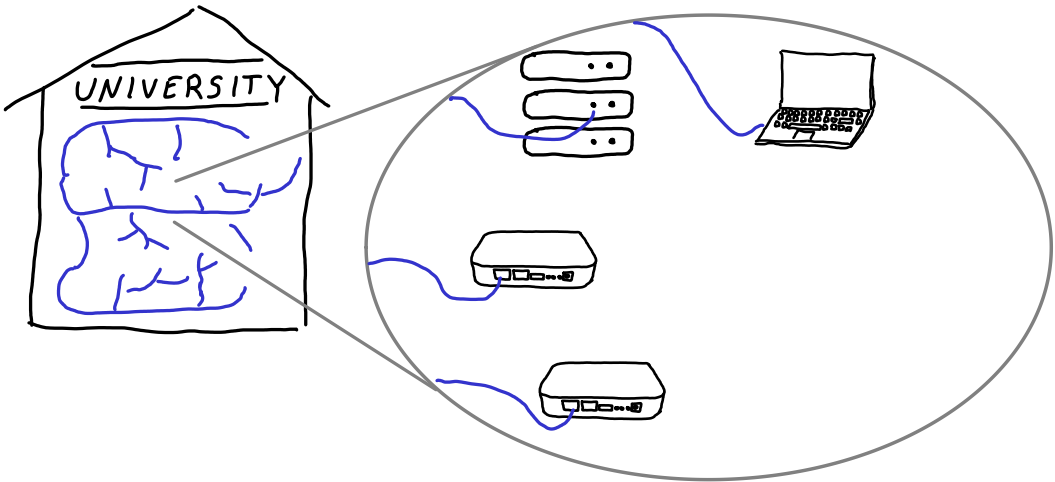
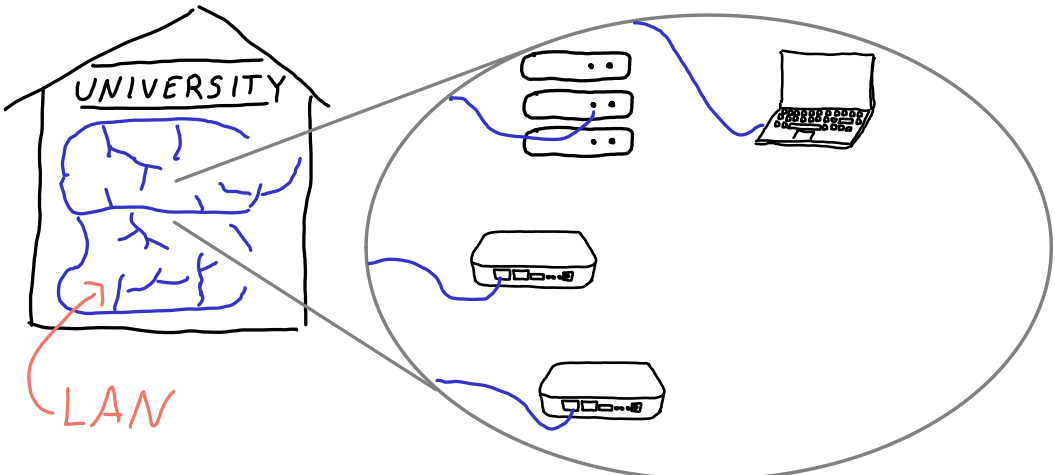
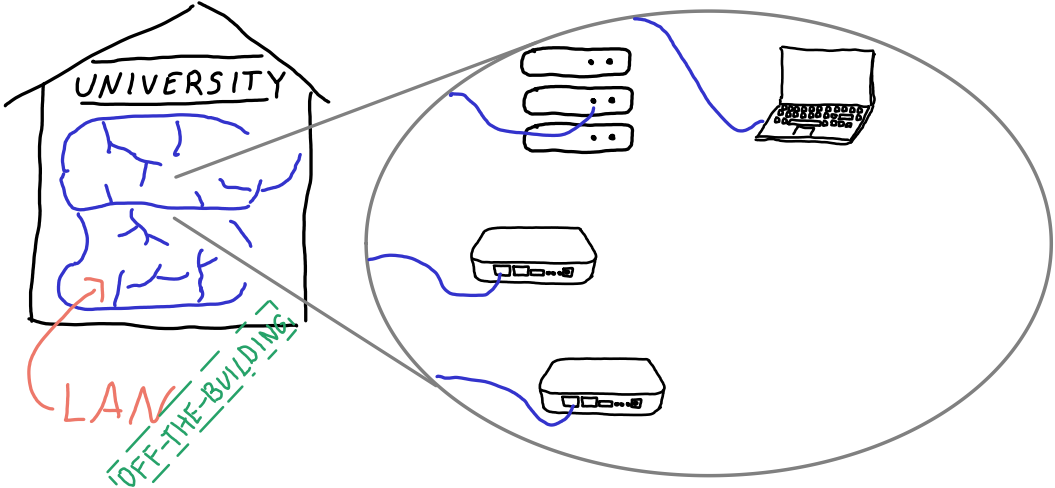


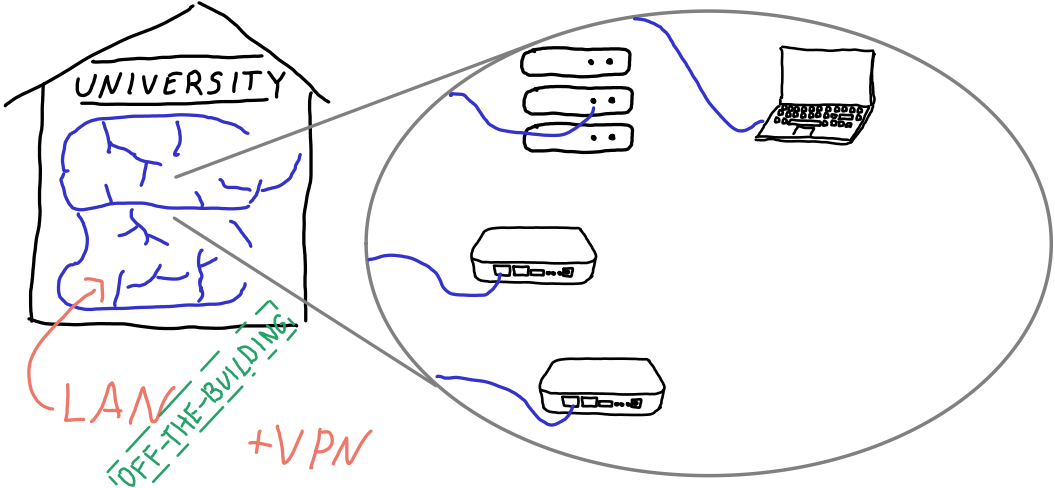
Design of the control network



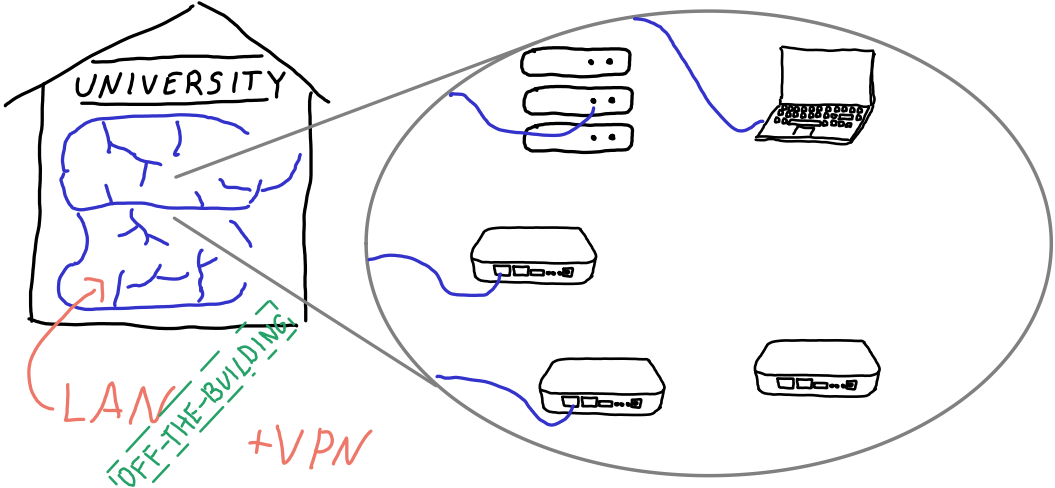
Design of the control network



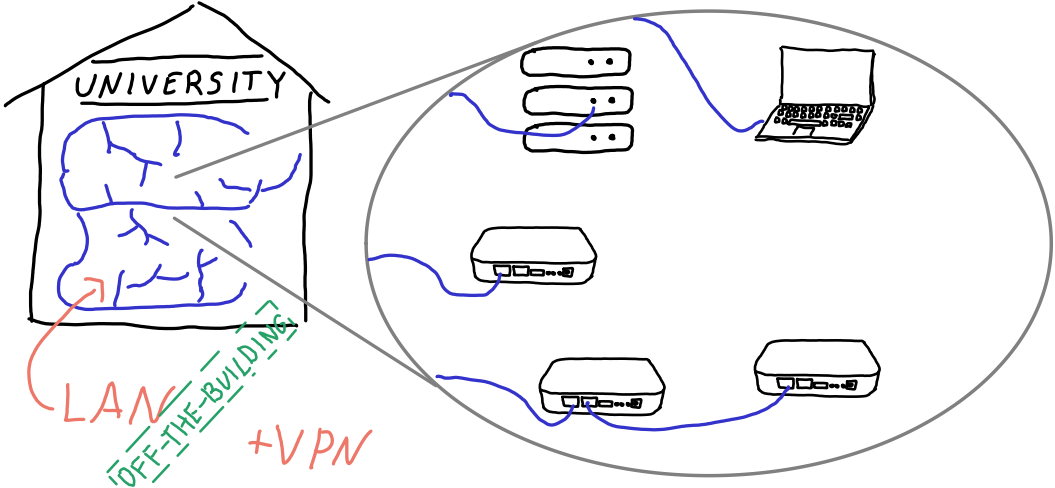
Design of the control network



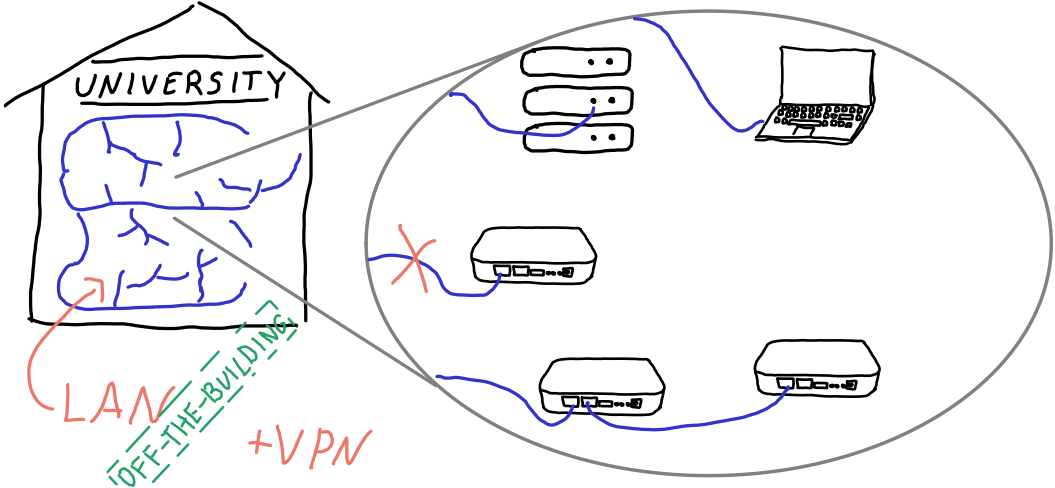
Design of the control network



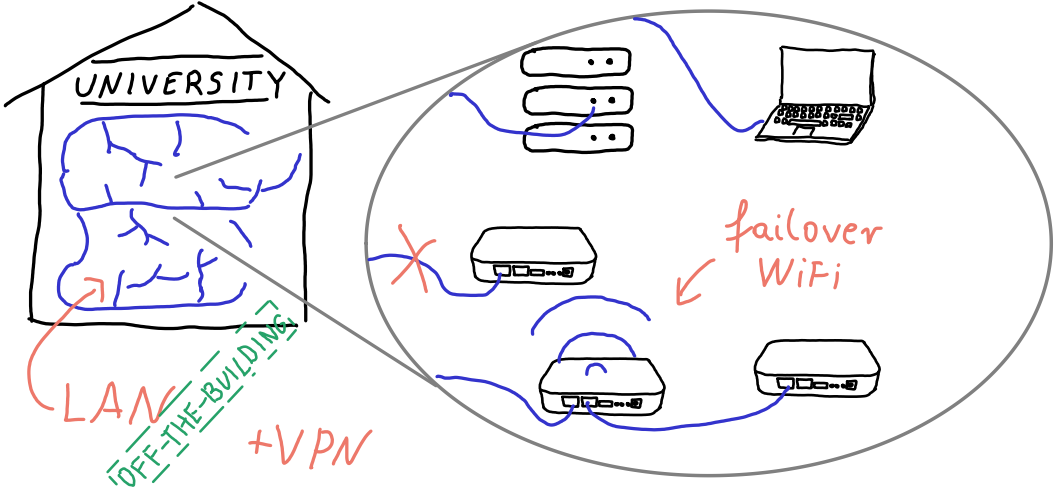
Design of the control network



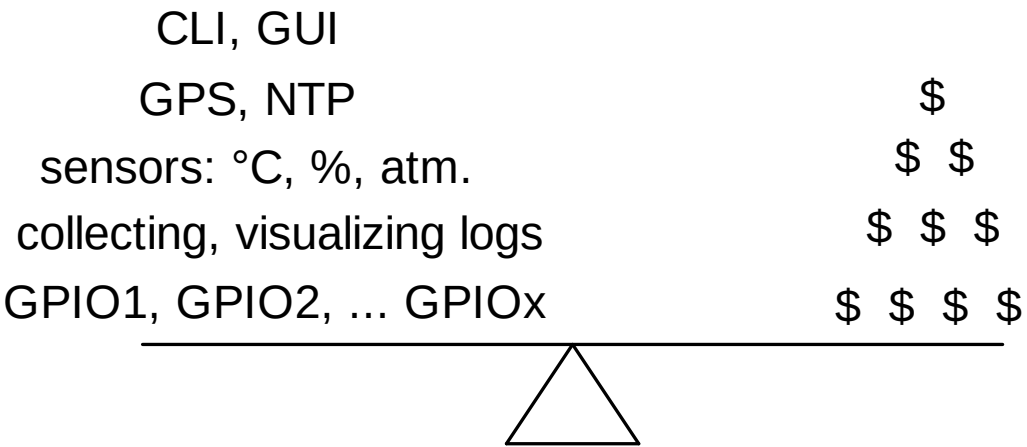
Design of the control network



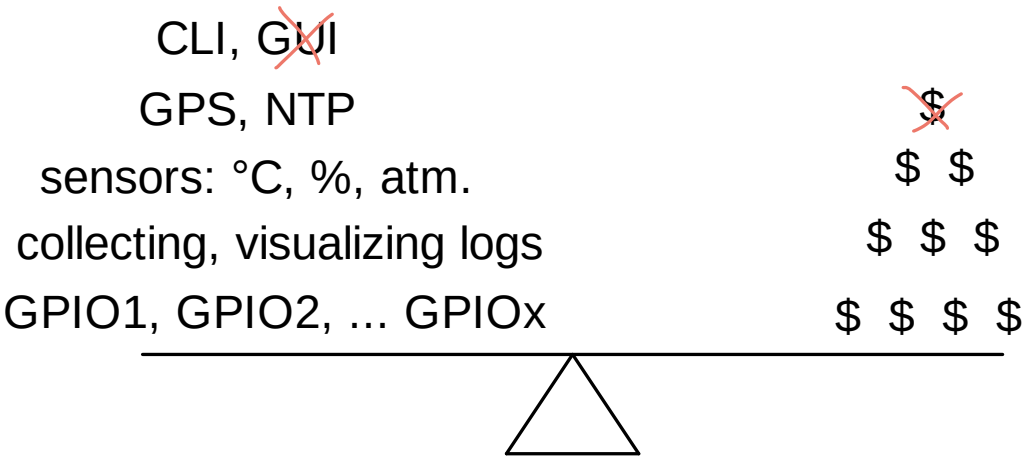
Design of the control network



Only essential features



Only essential features



Only essential features

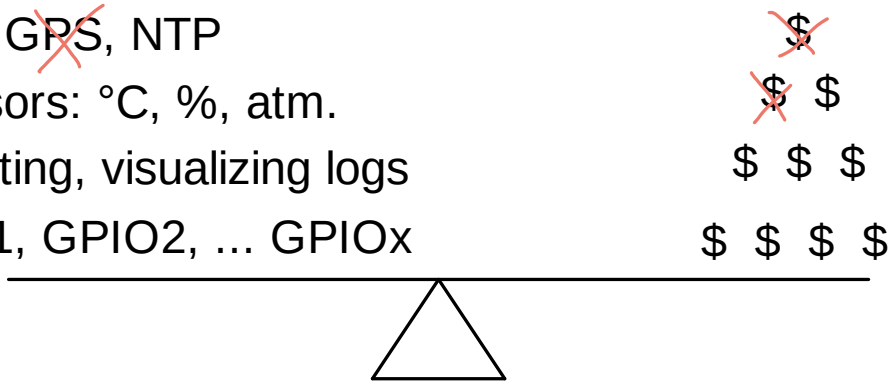
CLI, ~~GUI~~

~~GPS~~, NTP

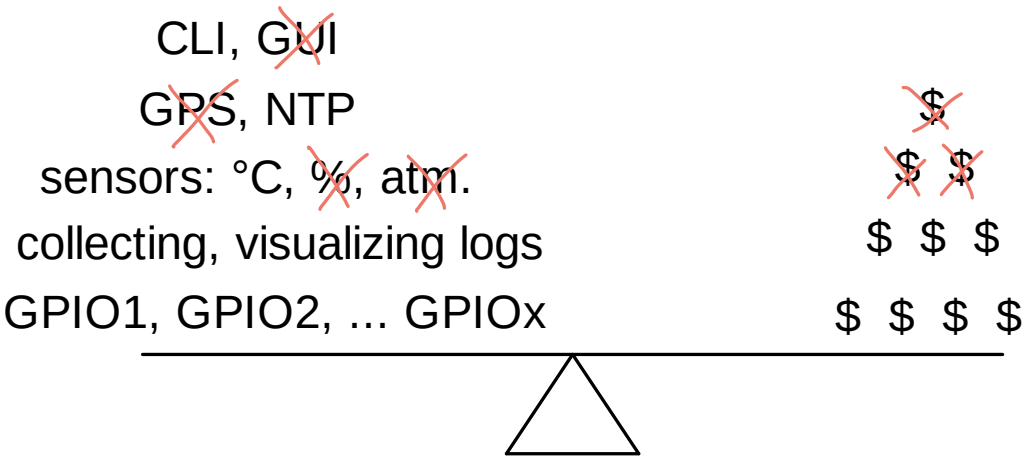
sensors: °C, %, atm.

collecting, visualizing logs

GPIO1, GPIO2, ... GPIOx



Only essential features



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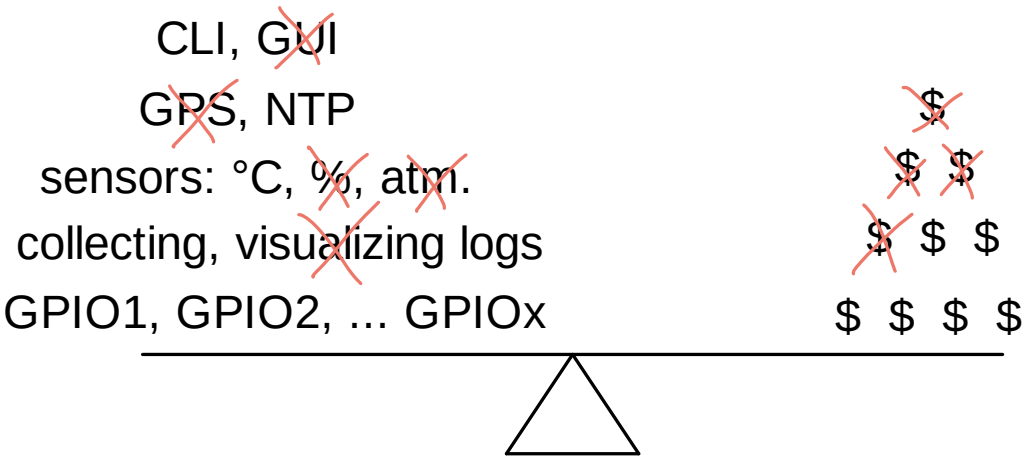

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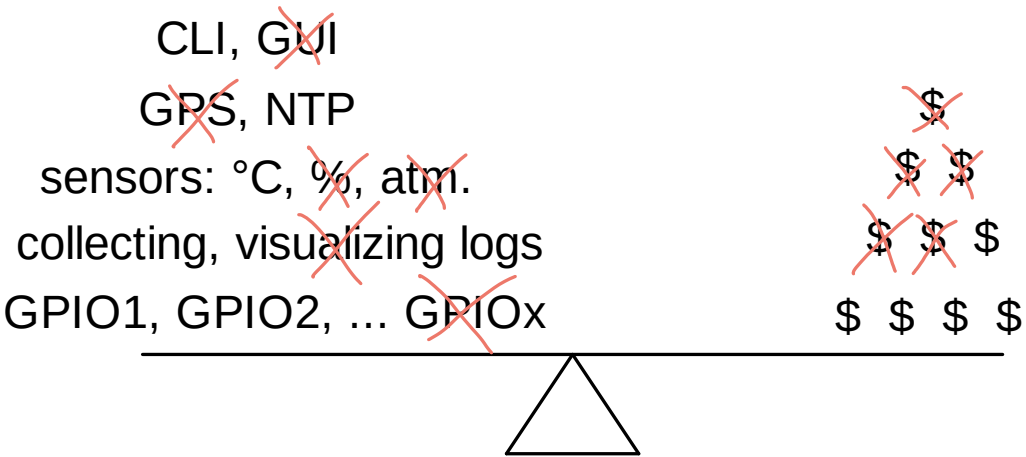

Costs of 1KT

Costs of 1KT

18 people

Costs of 1KT

18 people

4 years
$0.27M

Costs of 1KT

18 people

4 years
$0.27M

$85 x 1000

Costs of 1KT

18 people

$11,000

4 years
$0.27M

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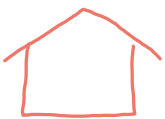


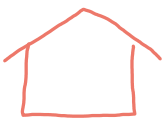
240h
$0

Costs of 1KT

18 people

$11,000

4 years
$0.27M



240h
$0

$85 x 1000

2.5kW

“What is your contribution?”

We contribute

- The 1KT testbed.

We contribute

- The 1KT testbed.
- Large-scale testbeds can be affordable.

We are open to collaboration

https://www.mimuw.edu.pl/~iwanicki/projects/heni/1kt.html

bit.do/1kt-uw

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Run experiments on 1KT

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Get connectivity graph

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bit.do/1kt-uw

Get connectivity graph

Get hardware schematics & design files

We are open to collaboration

Run experiments on 1KT

Replicate 1KT

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Thank You!

1KT: A Low-Cost 1000-Node Low-Power Wireless IoT Testbed

M. Banaszek, W. Dubiel, J. Łysiak, M. Dębski, M. Kisiel, D. Łazarczyk, E. Głogowska, P. Gumienny, C. Siłuszyk, P. Ciołkosz, A. Paszkowska, I. Rüb, M. Matraszek, S. Acedański, P. Horban, K. Iwanicki

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bit.do/1kt-uw

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The National Centre for Research and Development

LIDER

National Science Centre Poland