Indriya: A Low-Cost, 3D Wireless Sensor Network Testbed

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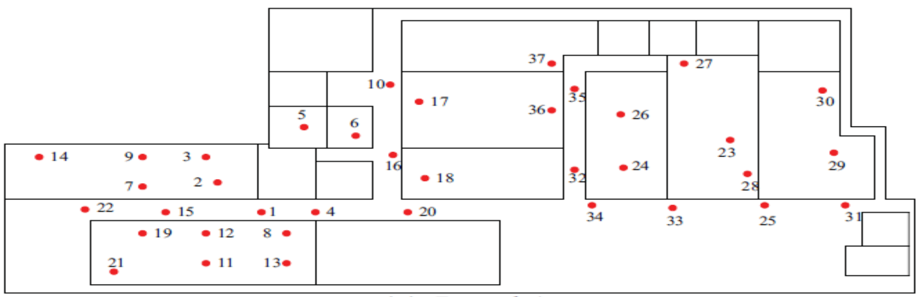
Outline

- Indriya
  - Deployment
  - Uses and Users
  - Design
  - Comparison
- Analysis of Channel Diversity
  - Performance differences and corrletions among different channels
  - Correlations and short-time stability of RSSI on different channels

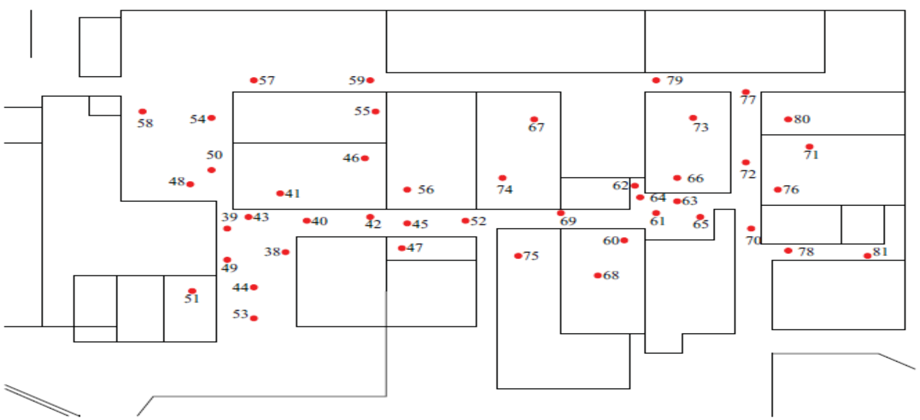
Indriya: Deployment

- Motes and sensors
  - Totally 127 TelosB motes are deployed over three floors of our building
  - More than 50% of the motes have sensors
    - WiEye – Often used to detect human beings
    - SBT80 – Contains ambient sensors
    - SBT30 and TelosB sensors – Used for education purposes

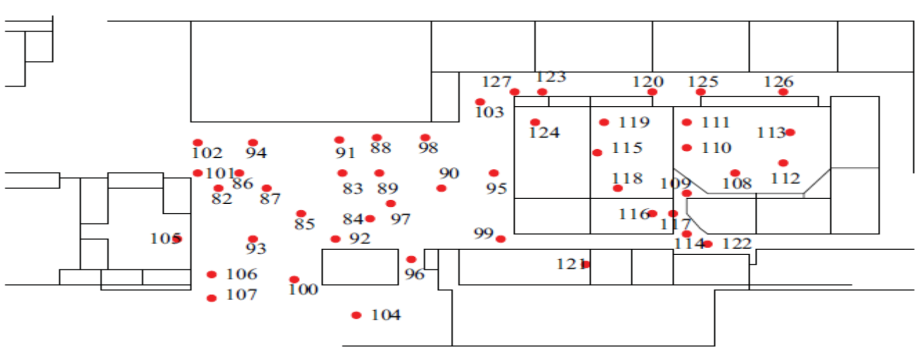
Deployment over 3 Floors



(a) Level 1



(b) Level 2



(c) Level 3

Uses and Users

- Indriya is in use for almost 2 years and it is being used for both research and teaching
  - Users often use it for evaluating their research work on networking protocols
  - There are over 100 users from more than 35 Universities
    - Universities include Xi'an Jiaotong University and HIT in China

Uses and Users

- We are also using it in teaching a course on WSNs
- Our School also uses Indriya to monitor temperature in its building so that air conditioners can be set accordingly

Design

- Existing designs

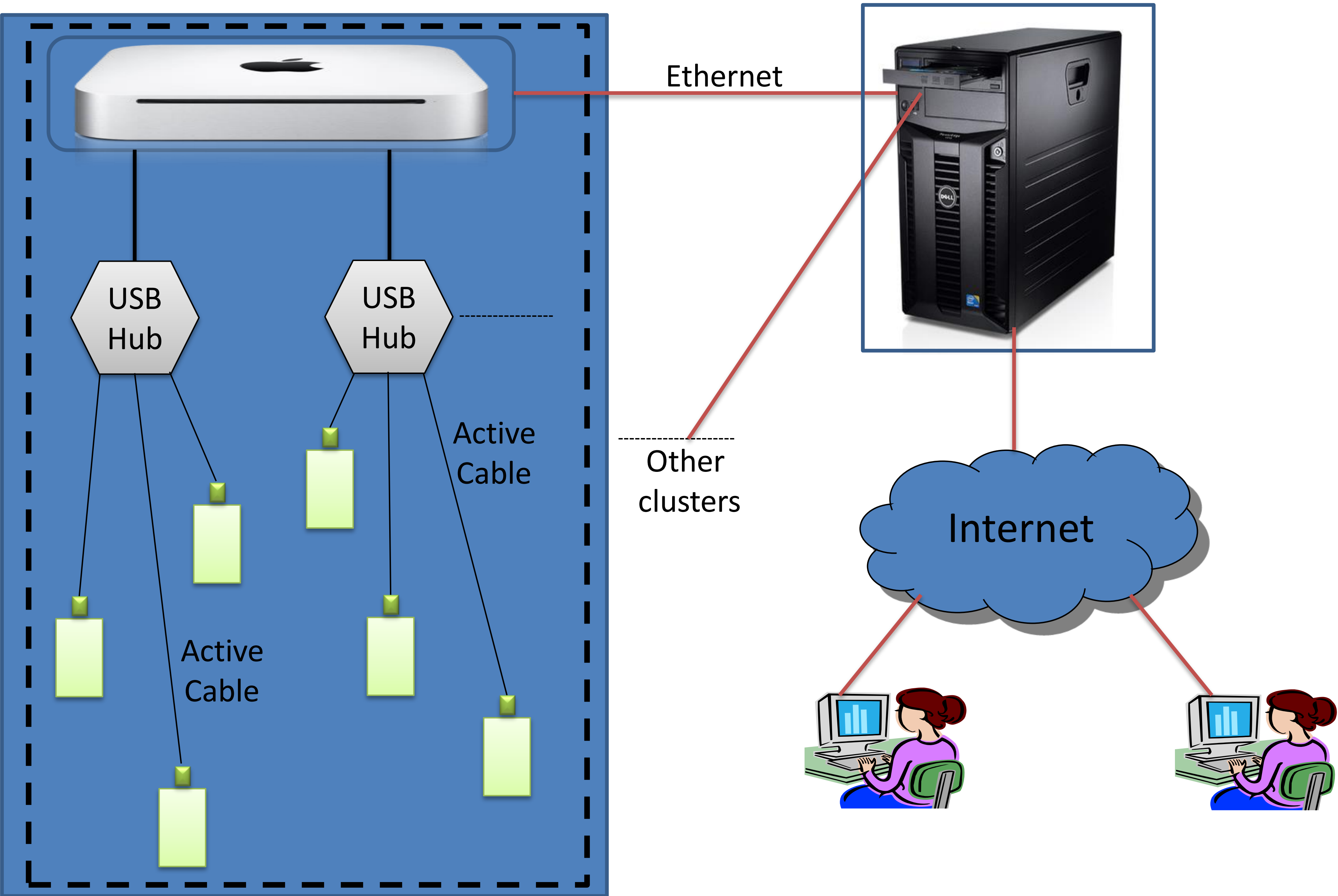
One-to-one architecture used by Motelab and Kansei

One-to-many architecture adopted by Twist

Design (Contd..)

- Indriya also incorporates one-to-many design but an efficient one with MAC Mini PCs constituting cluster heads
- We are able cover our large building with only 6 clusters with each cluster capable of accommodating 127 devices

Design (Contd..)



Comparison

- We discuss advantages of our design by comparing against Motelab, Kansei, and Twist testbeds
  - We gain mainly in terms of costs for deployment and maintenance

Motelab	Kansei	Adopting design of Twist	Indriya
US$548+	US$548+	US$223+	US$153

Estimated average cost per node in different testbeds

Comparison (contd..)

- All the other three testbeds use a large number of single-board computers such as NSLU2
  - Setting-up and maintaining these computers is both expensive and pains-taking

Comparison (contd..)

- Every single-board computer should be wall-powered
- Requires customized OS and mote-programming tools
- Such devices are typically resource-constrained thus demanding requirements such as file system over network

Comparison (contd..)

- On contrary, Indriya uses only 6 MAC Mini PCs although it covers larger geographical volume than other testbeds
  - Indriya is the largest deployment with its bounding cube measuring 23500 m^3
- PC-class MAC Mini can use desktop OSs and standard programming tools without any testbed-specific modifications

Comparison (contd..)

- Maintenance cost of Indriya for almost 2 years of its operation is minimal
  - We have spent less than US$500 till date with most of it incurred in replacing failed ac-to-dc adaptors used to power USB hubs
  - Maintenance cost in terms of time required is one to two hours per week time of one PhD student

Constituents of Indriya

Device	Vendor
Motes	Memsic's TelosB
Sensors	EasySen
Active cables	ATEN
USB hubs	Belkin's 7-port hubs
Cluster head	Apple MAC Mini

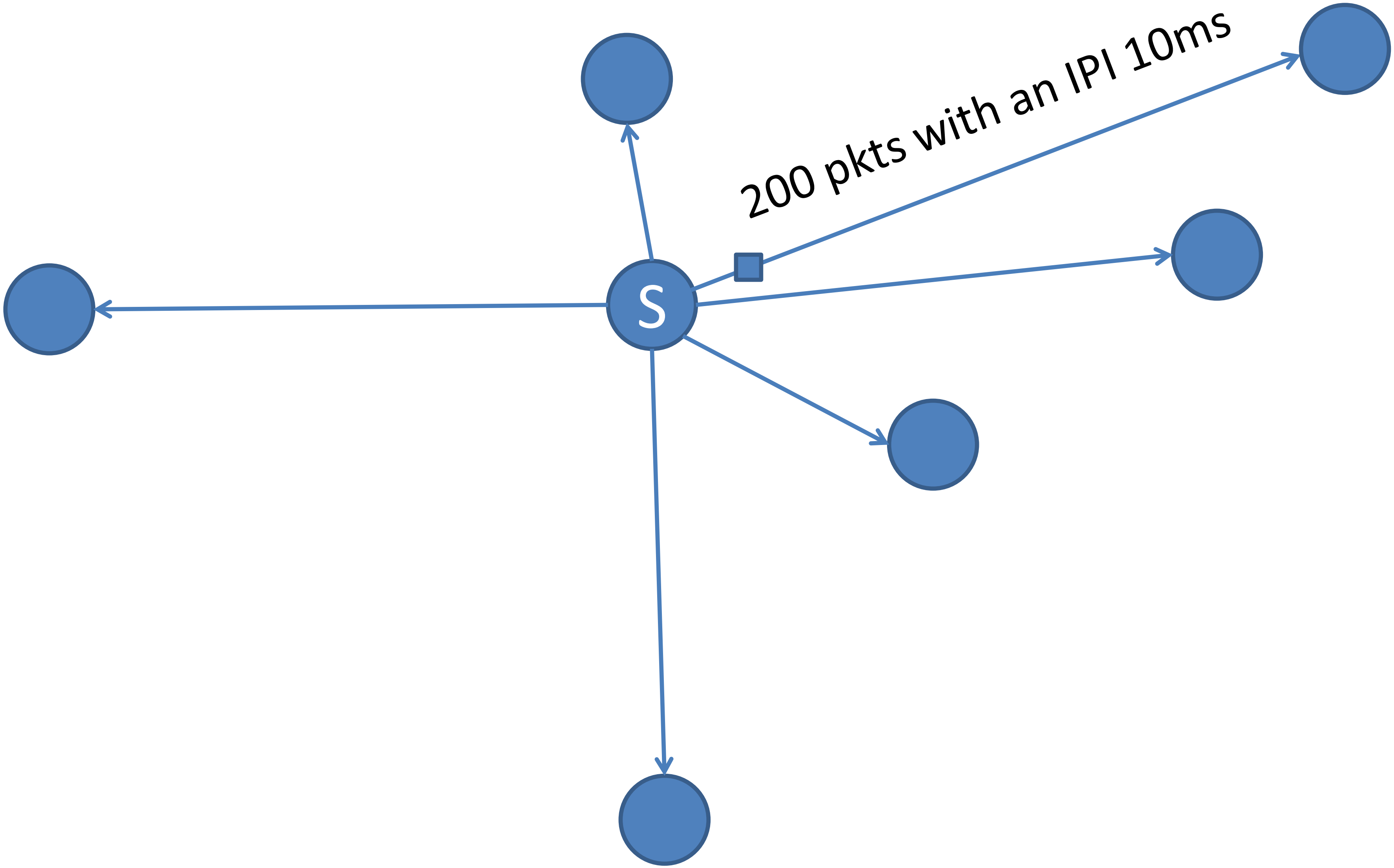
It is very important to use high quality active cables, USB hubs, and ac-to-dc adaptors for the hubs.

Experimental Analysis of Channel Diversity

Goals

- Our two goals are as follows
  1) To analyze performance differences and correlations that may exist among 16 non-overlapping channels of IEEE802.15.4 supported by CC2420 devices on Indriya
  2) To verify generality of the correlation of RSSI with PRR [Hotnets'06] and its short-time stability [SenSys'08] across different channels

Experimental Methodology



Experimental Methodology

- We repeat this process on each of the 44 nodes spanning an entire floor of Indriya thus considering a maximum of 44 * 43 = 1892 links
- Moreover, we repeat the entire procedure on each of the 16 channels

Performance Differences

- Number of communication links differ from channel to channel
- Although avg. no. of links per channel is 633, only 392 links are commonly found on all 16 channels

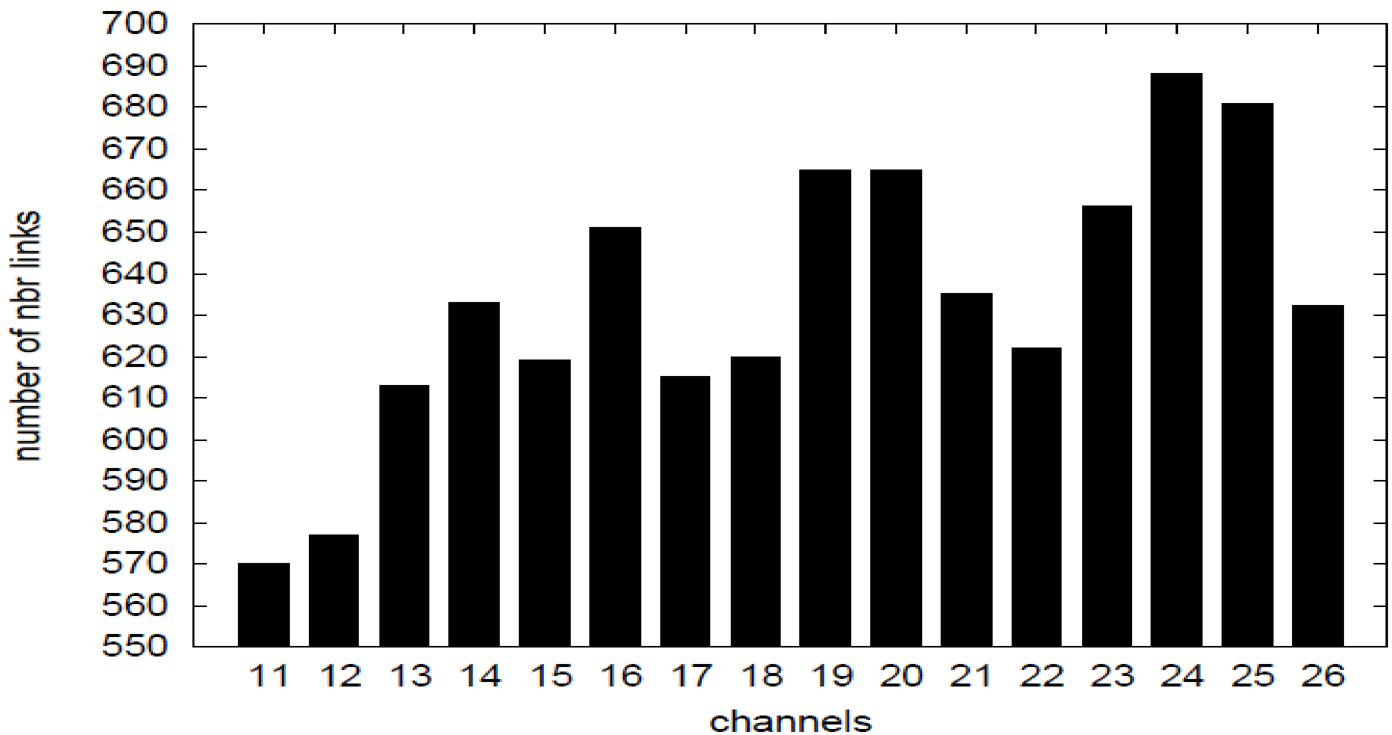


Figure 1. Network-wide variations

Performance Differences (Contd..)

- Link-wise variations

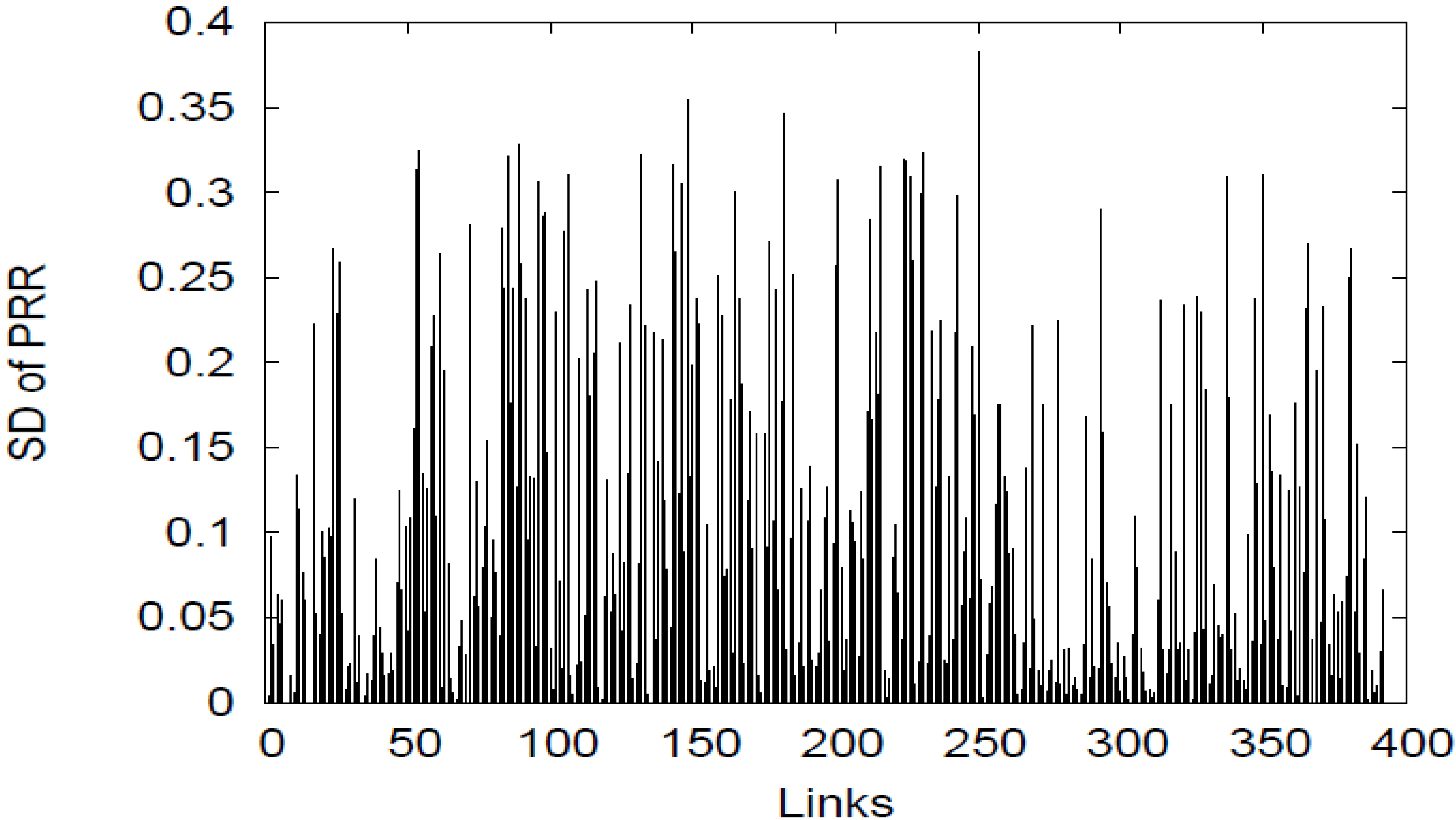


Figure 2. Link-wise variations

Correlation among Channels

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
11	0.00	0.22	0.48	0.33	0.10	0.20	0.18	0.16	0.18	0.09	0.07	0.11	0.17	0.12	0.02	0.03
12	0.61	0.00	0.67	0.45	0.16	0.32	0.32	0.26	0.27	0.14	0.14	0.20	0.26	0.20	0.04	0.04
13	0.42	0.23	0.00	0.29	0.08	0.19	0.15	0.13	0.15	0.08	0.06	0.10	0.19	0.12	0.02	0.04
14	0.52	0.39	0.58	0.00	0.10	0.27	0.25	0.23	0.26	0.13	0.13	0.20	0.26	0.21	0.03	0.03
15	0.70	0.58	0.81	0.65	0.00	0.47	0.50	0.44	0.45	0.31	0.28	0.42	0.47	0.36	0.10	0.06
16	0.61	0.44	0.70	0.49	0.16	0.00	0.33	0.30	0.30	0.18	0.17	0.25	0.31	0.23	0.06	0.04
17	0.68	0.49	0.73	0.53	0.18	0.39	0.00	0.35	0.35	0.22	0.21	0.31	0.39	0.28	0.06	0.04
18	0.68	0.50	0.76	0.57	0.20	0.42	0.36	0.00	0.36	0.21	0.19	0.28	0.38	0.25	0.07	0.05
19	0.65	0.49	0.74	0.54	0.19	0.38	0.35	0.33	0.00	0.18	0.19	0.31	0.34	0.24	0.06	0.05
20	0.73	0.60	0.80	0.62	0.23	0.47	0.45	0.41	0.43	0.00	0.28	0.39	0.44	0.34	0.09	0.06
21	0.73	0.58	0.82	0.62	0.24	0.49	0.49	0.43	0.45	0.26	0.00	0.36	0.44	0.31	0.08	0.06
22	0.71	0.54	0.79	0.59	0.22	0.46	0.45	0.41	0.40	0.24	0.20	0.00	0.39	0.29	0.08	0.05
23	0.67	0.50	0.73	0.57	0.19	0.43	0.38	0.34	0.39	0.21	0.19	0.25	0.00	0.26	0.07	0.05
24	0.70	0.52	0.78	0.55	0.20	0.43	0.43	0.38	0.39	0.23	0.22	0.35	0.41	0.00	0.05	0.05
25	0.76	0.64	0.86	0.69	0.30	0.51	0.54	0.49	0.49	0.36	0.33	0.46	0.53	0.39	0.00	0.06
26	0.76	0.64	0.84	0.69	0.32	0.53	0.56	0.49	0.51	0.37	0.32	0.49	0.54	0.39	0.11	0.00

Table 1. The G-matrix

Correlation between PRR and RSSI

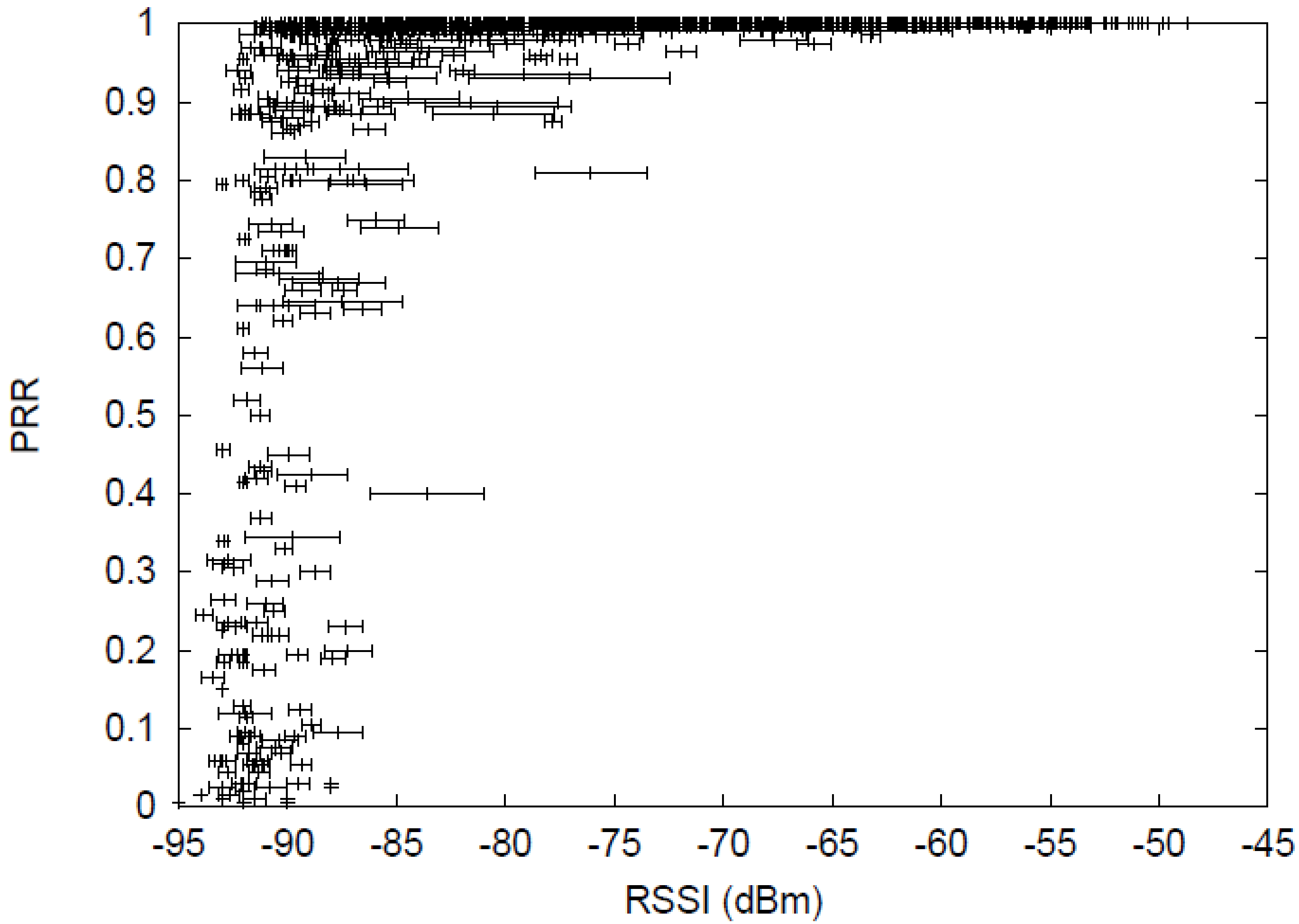


Figure 3. Correlation between PRR and RSSI on channel 15

Short-time stability of RSSI

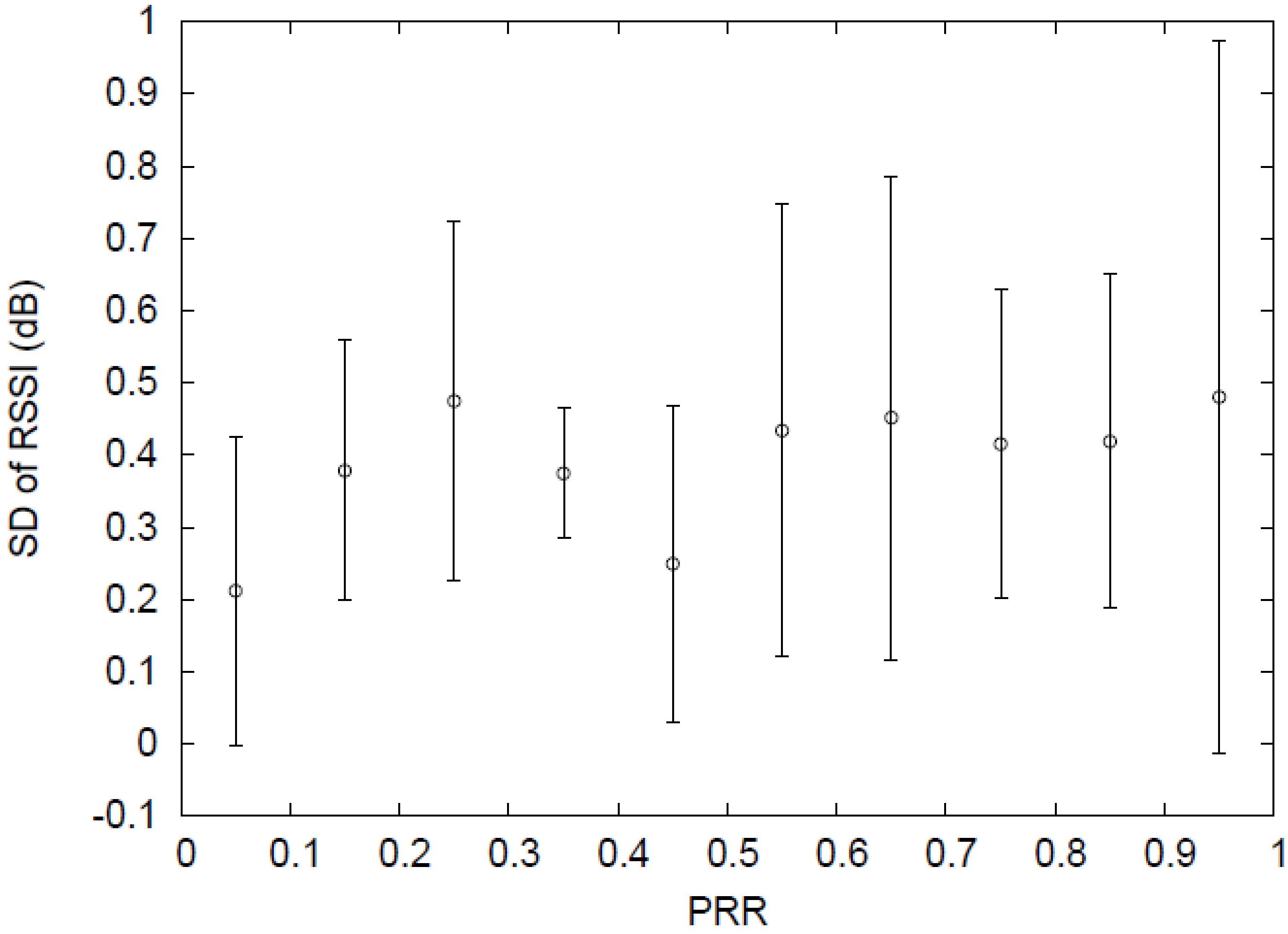


Figure 4. Short-time stability of RSSI on channel 21

Conclusion

- We demonstrated that large-scale testbeds can be reliably built over USB infrastructures without employing single-board computers
- The main advantage of our design is that it considerably reduces costs of both deployment and maintenance
- We also showed that performance varies drastically from channel to channel and demonstrated that well-known RSSI correlation to PRR and its short-time stability can be generalized across all channels