From Conception to Retirement: a Lifetime Story of a 3-Year-Old Wireless Beacon System in the Wild

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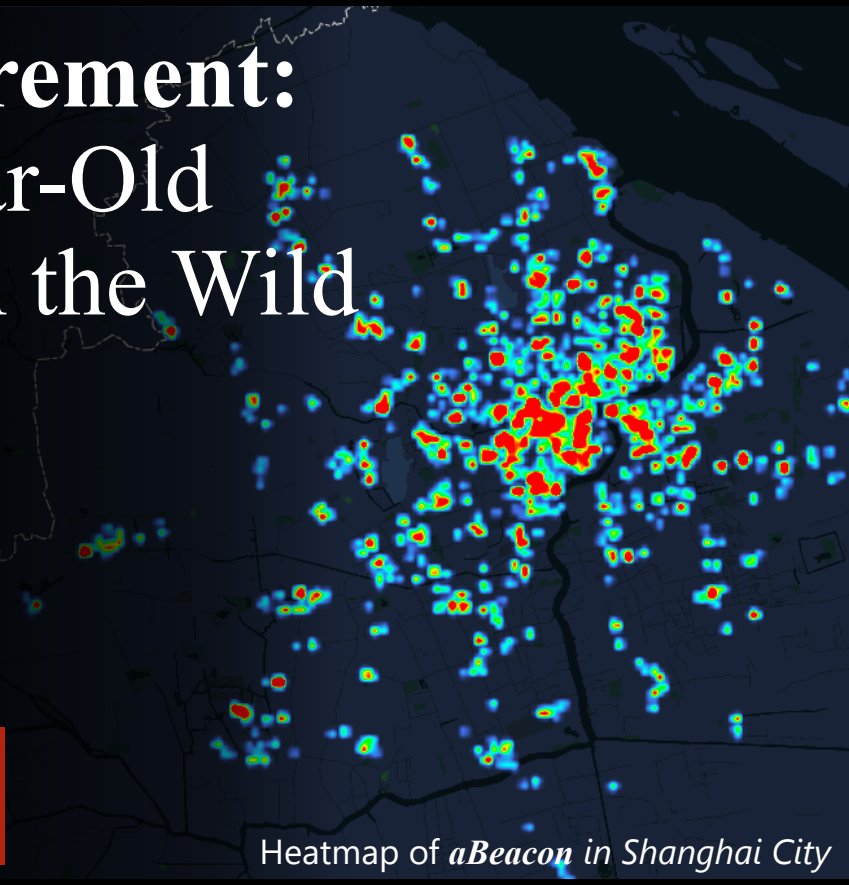


Heatmap of ***aBeacon*** *in Shanghai City*

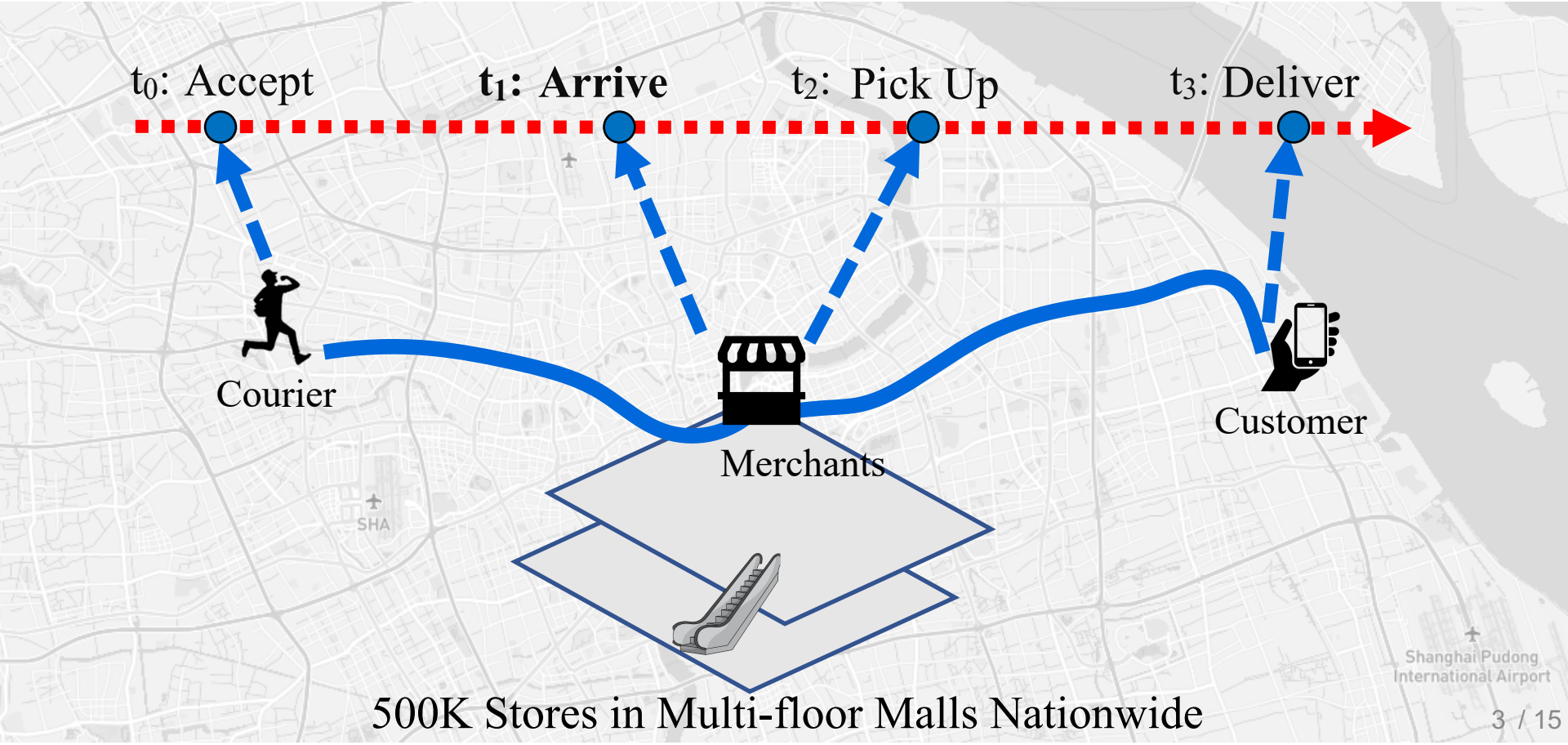
On-Demand Delivery (food/grocery)

A $107 Billion Market

3X Rider Sharing in 2019

- ResearchAndMarkets.com

Delivery Process



500K Stores in Multi-floor Malls Nationwide

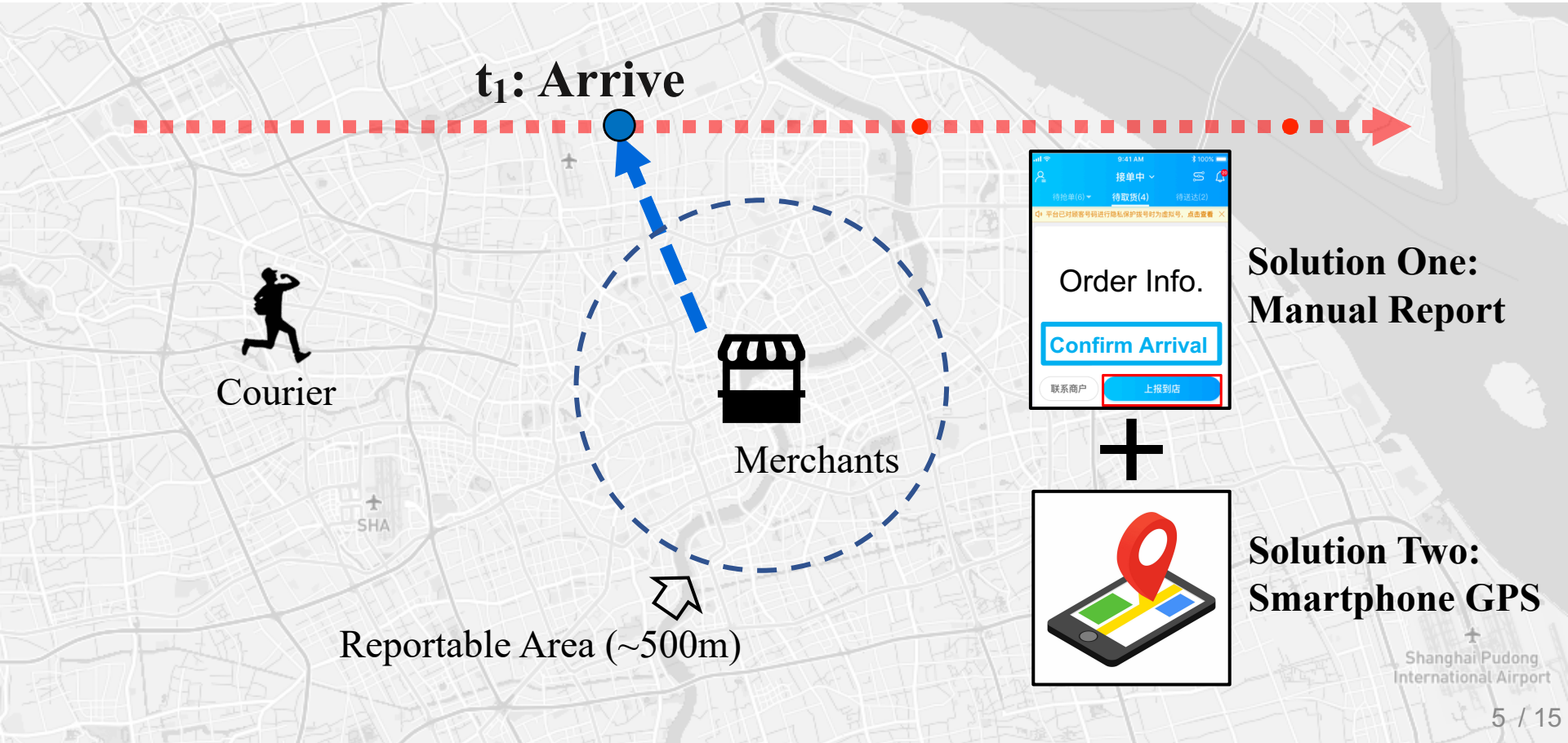
Why Accurate Arrival Time Matters?

Application One:
Order Dispatching
(Localization and Time Estimation)

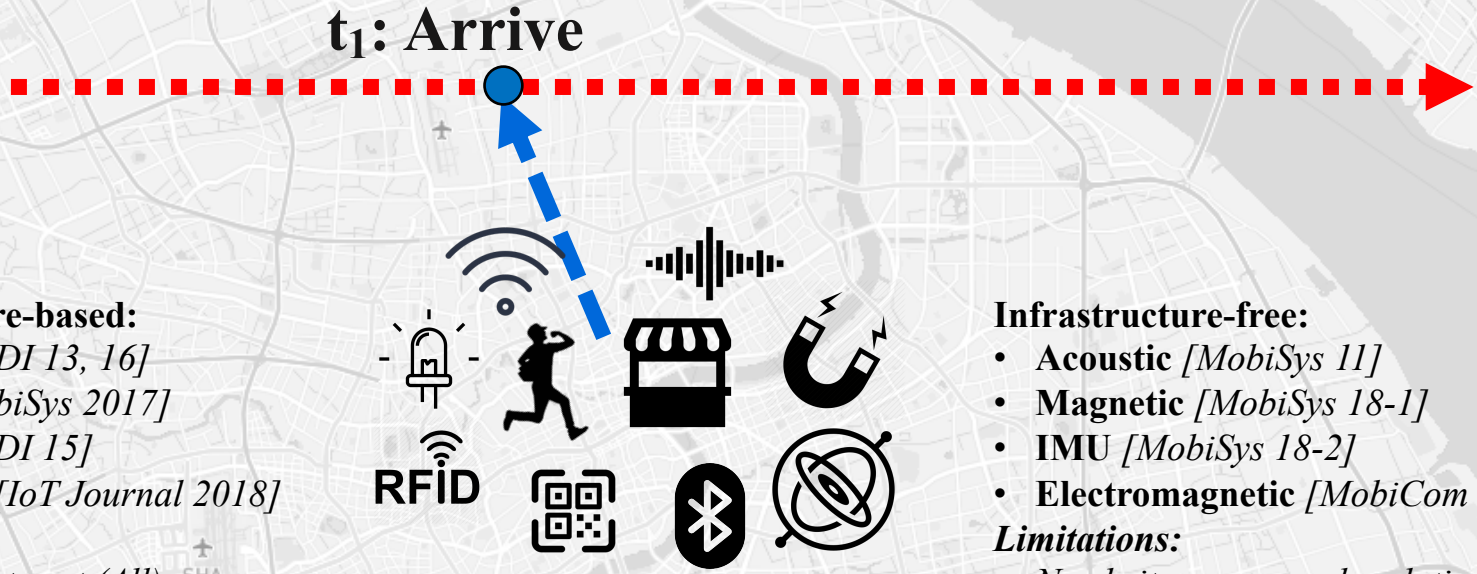
Application Two:
Overdue Order Investigation
(Late Arrival or Slow Preparation?)

Application Three :
Order Progress Demonstration
(Where is my meal?)

Industry State-of-Arts



Academy State-of-Arts



Infrastructure-based:
- **Wi-Fi** *[NSDI 13, 16]*
- **LED** *[MobiSys 2017]*
- **RFID** *[NSDI 15]*
- **QR Code** *[IoT Journal 2018]*

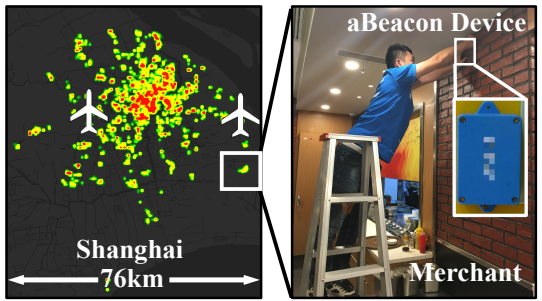
Limitations:
- *Deployment cost (All)*
- *Need hardware modification (LED)*
- *Restriction on smartphone hardware (RFID)*
- *Need manual effort (QR Code).*

BLE Beacon
- *Easy to deploy*
- *Accurate enough*
- *Transparent to couriers*
- *Acceptable cost (<$10 each)*

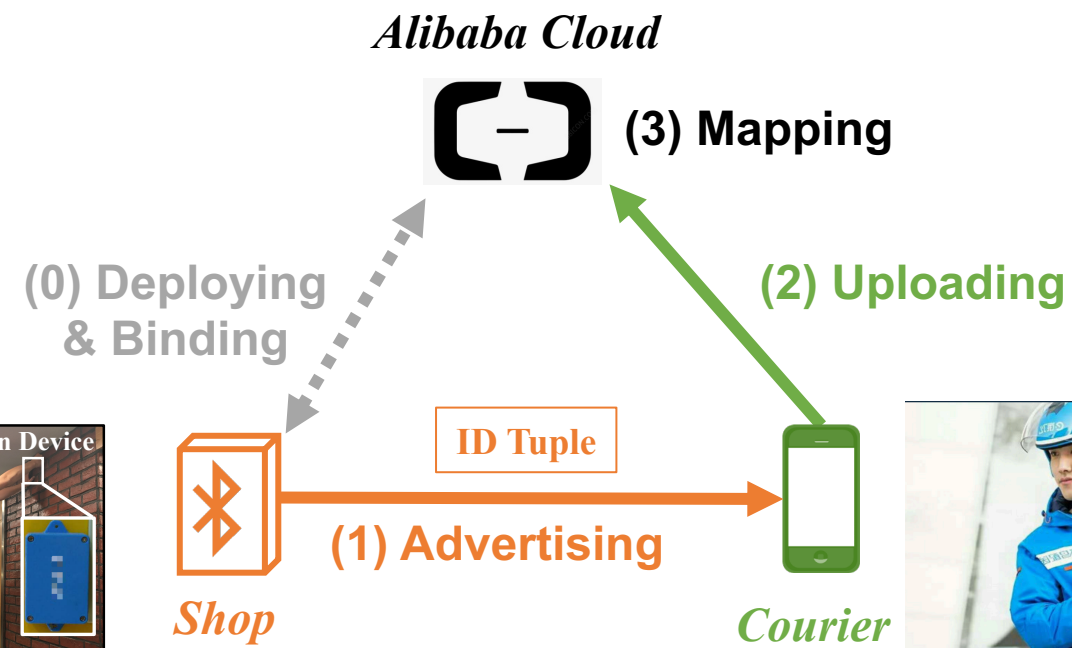
Infrastructure-free:
- **Acoustic** *[MobiSys 11]*
- **Magnetic** *[MobiSys 18-1]*
- **IMU** *[MobiSys 18-2]*
- **Electromagnetic** *[MobiCom 18]*

Limitations:
- *Need site survey and updating*
- *Cannot be applied to dynamic environment*

aBeacon System – Alibaba Beacon System

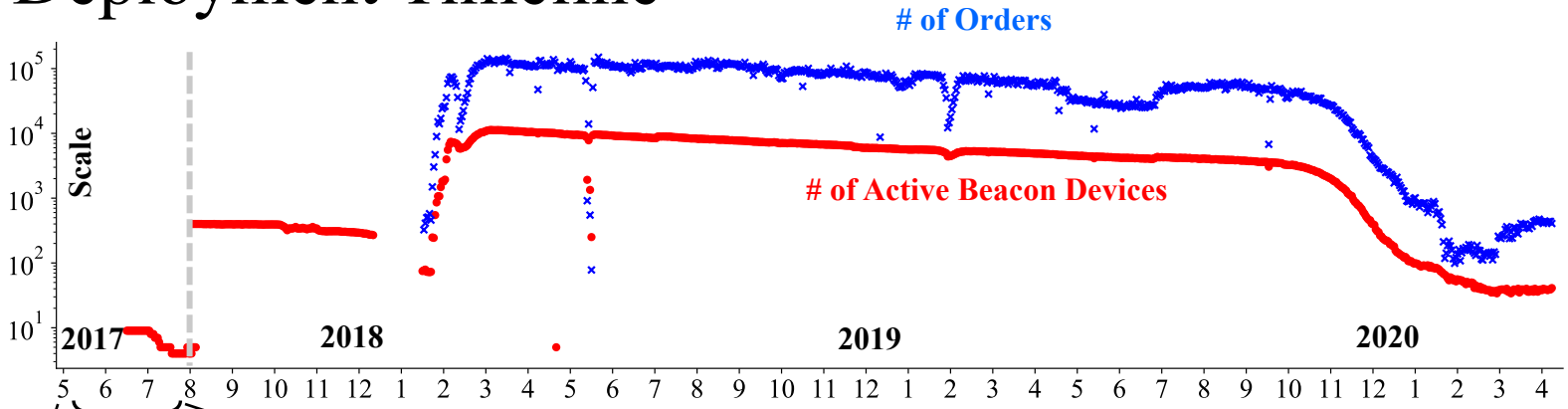


12,000+ shops



110,000+ couriers

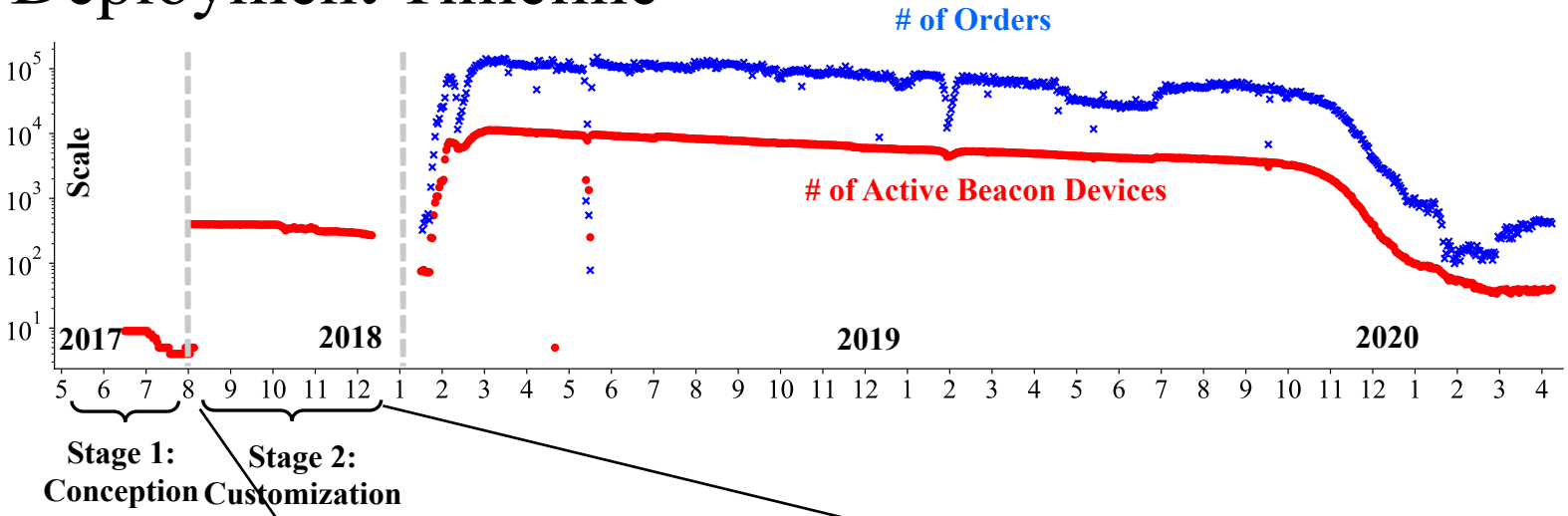
Deployment Timeline

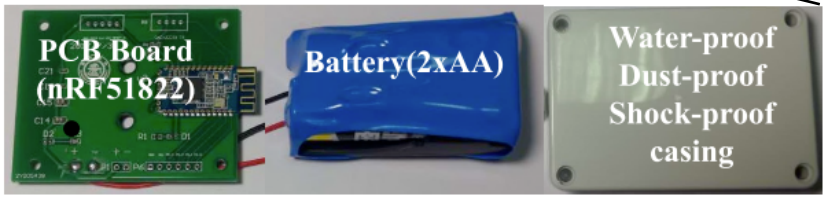


Stage 1: Conception

 Size Comparison	 Device 1 (T15)	 Device 2 (T4)	 Device 3 (T11)
Tx Power	-59 dB	-65 dB	-65 dB
Advertised Lifetime	≤ 3 yr	2 ~ 3 yr	≤ 3 yr
Cost	$11 each	$10 each	$10 each
Encapsulation	—	Water, Dust, Shock Proof	Dust Proof Only

Deployment Timeline

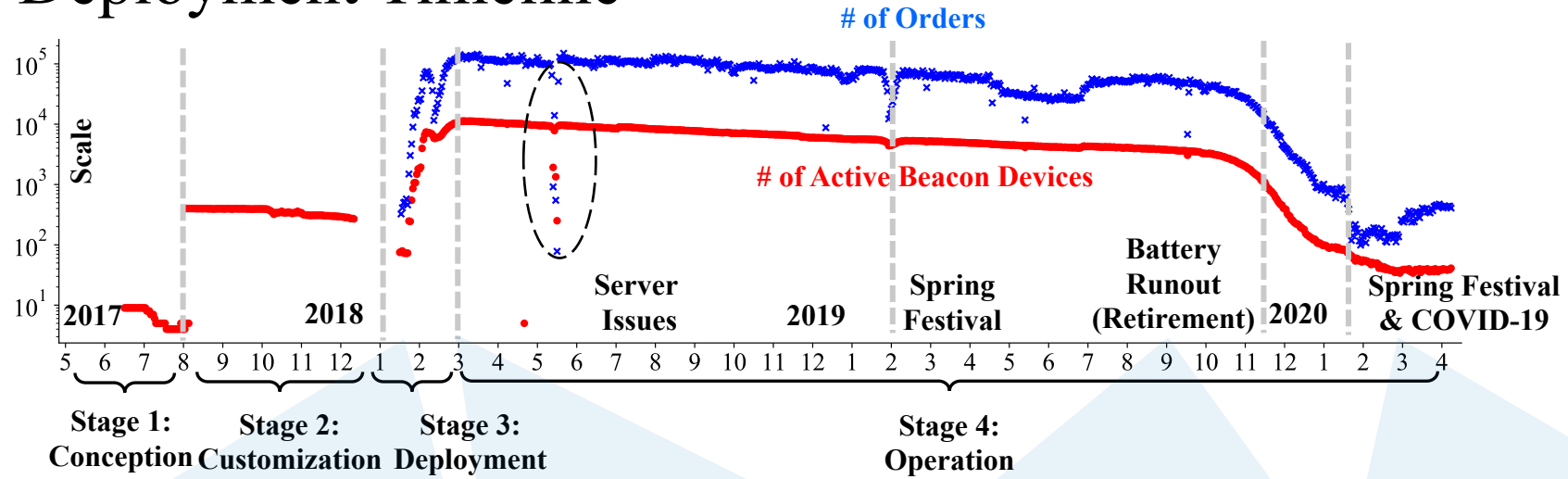


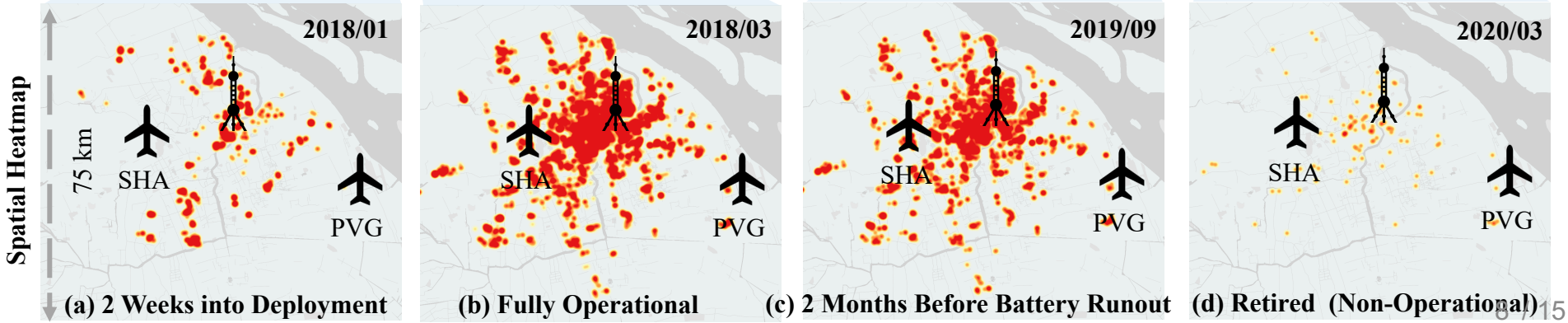


Customized beacon devices:

- Less cost ($8 each)
- Longer lifetime (>=2 years)

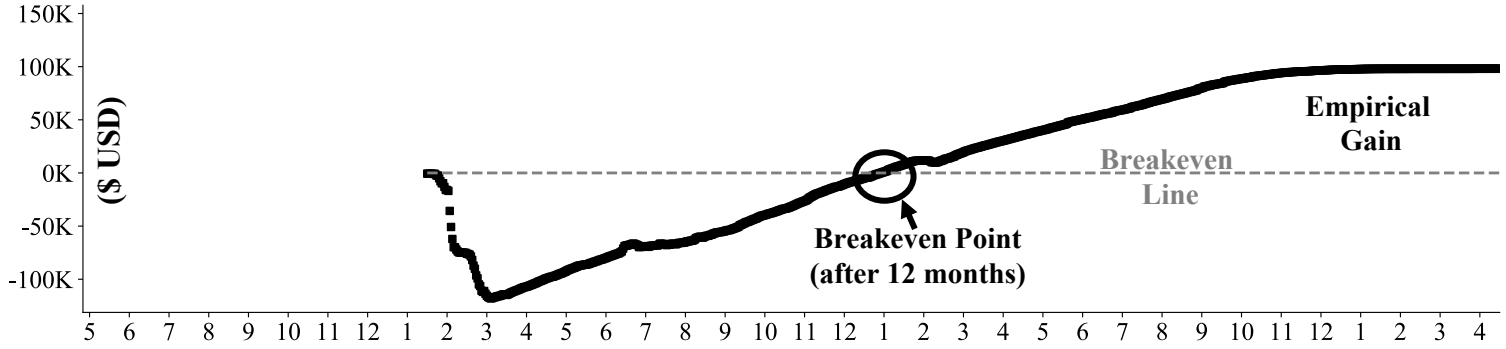
Deployment Timeline

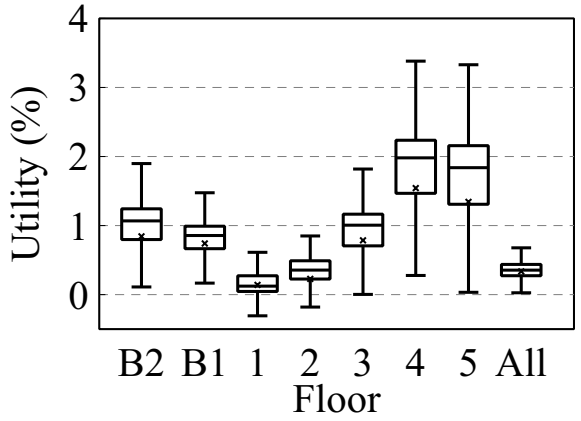




Performance: Utility (*overdue ratio reduction*)

Cumulative Gain = Cumulative Utility - Cost



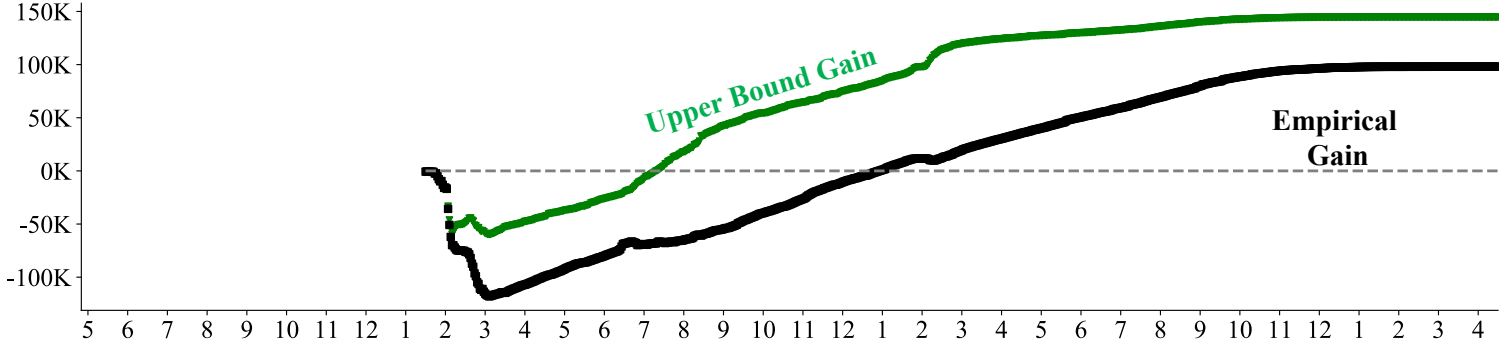


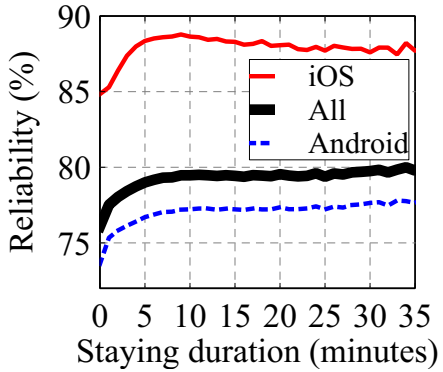
Impact of Floor

Observation: aBeacon is more beneficial in ***higher floors*** *and* ***basements***

Performance: Reliability

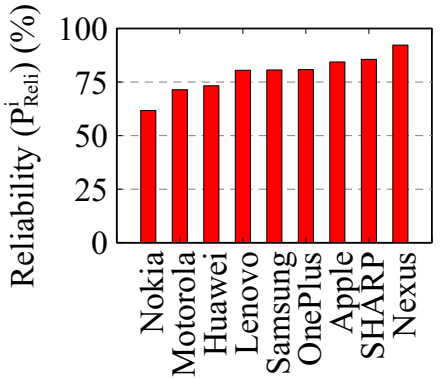
(*how many arrival events can be detected among all events?*)





Impact of Staying Duration

Android Reliability	iOS Reliability
75%	85%



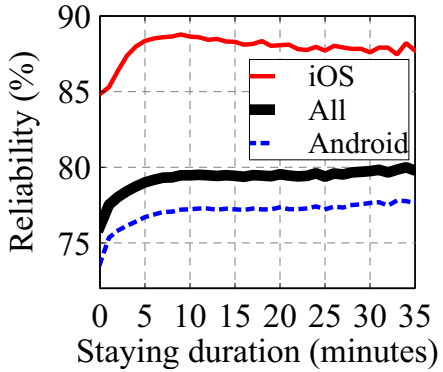
Impact of Smartphone Hardware

Performance: Reliability

(*how many arrival events can be detected among all events?*)

Lesson Learned: Reliability in the Wild

***Even** for arrival detection, the reliability is far from guaranteed in the wild due to multiple factors.*



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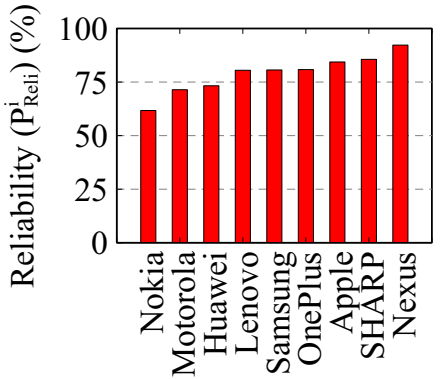
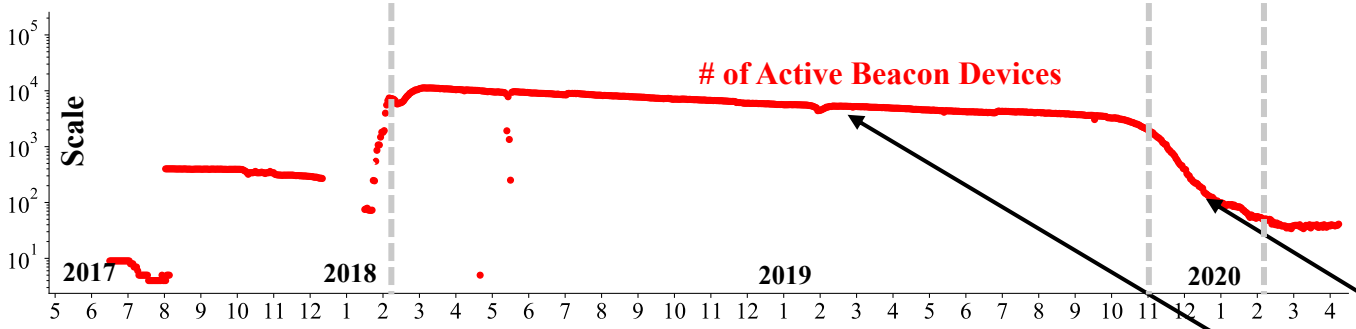
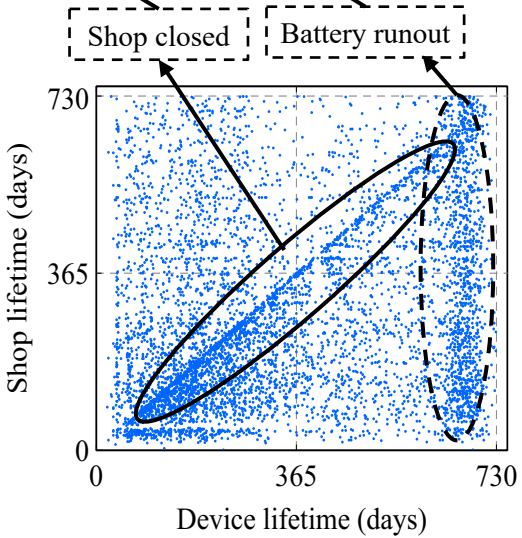


Impact of Smartphone Hardware

Performance: Lifetime (*the lifetime of each device*)





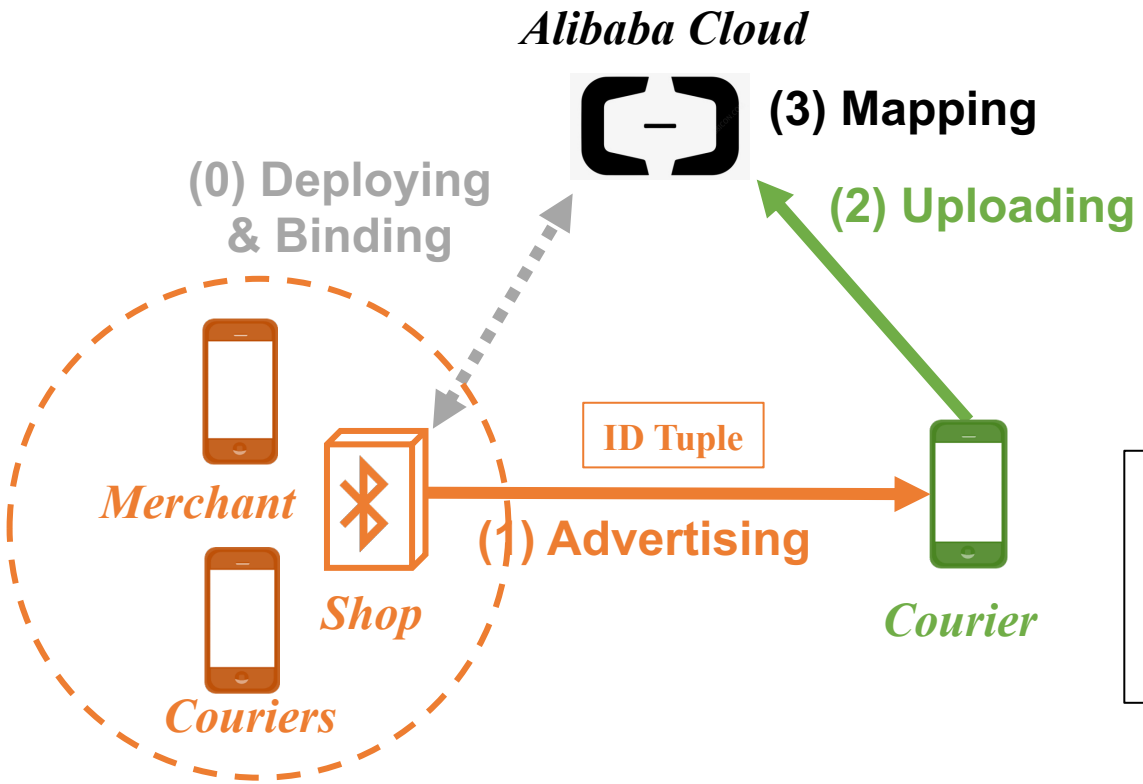
Lesson Learned: Lifetime in the Wild

- *Battery may NOT be the major constraint for mobile/wireless devices, since 40% devices survive longer than the environment (i.e., shops).*

Implication for Building Industrial Systems

	System Evolution	Reliability	Lifetime
Lessons	Physical devices fail earlier than expected.	Wireless beacon devices are NOT reliable (for regulation).	Device lifetime are significantly affected by the environment.
Implication	Adopt existing devices.	Hybrid solutions (BLE+GPS+Manual Report)	Adaptive battery design.

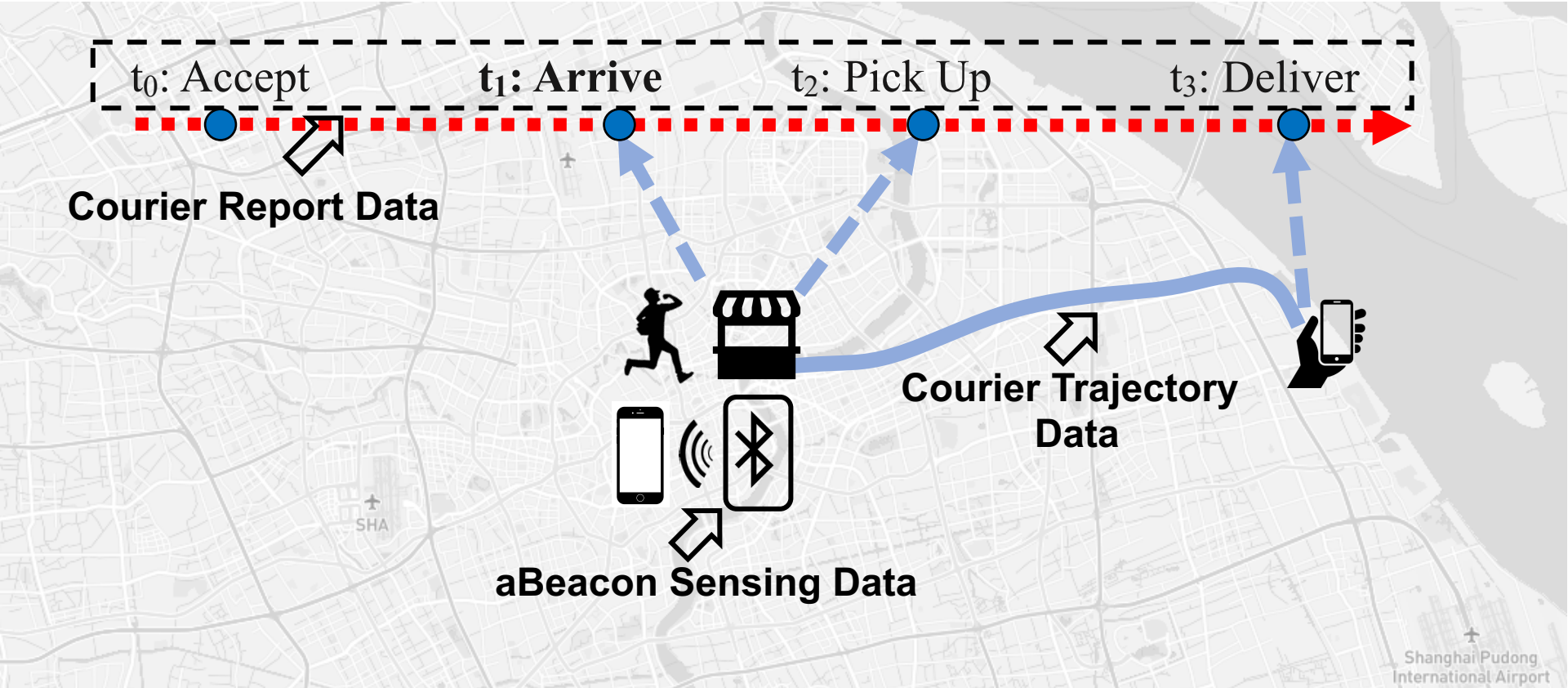
Next Generation of aBeacon: aBeacon+



- No hardware or deployment cost.
- No lifetime worries.
- No battery worries.
- Hybrid solution.

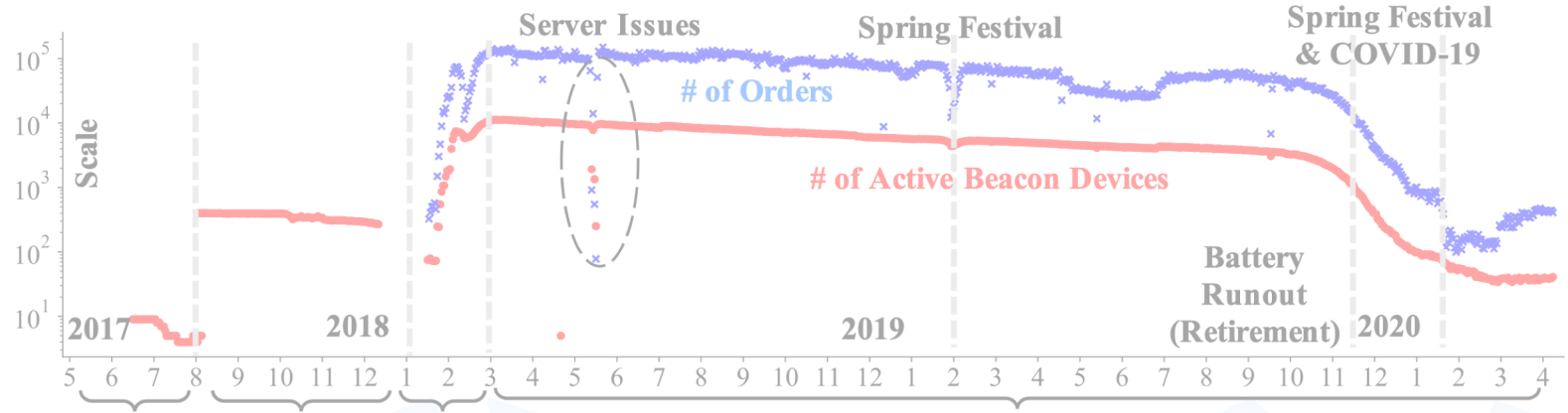
Data Release

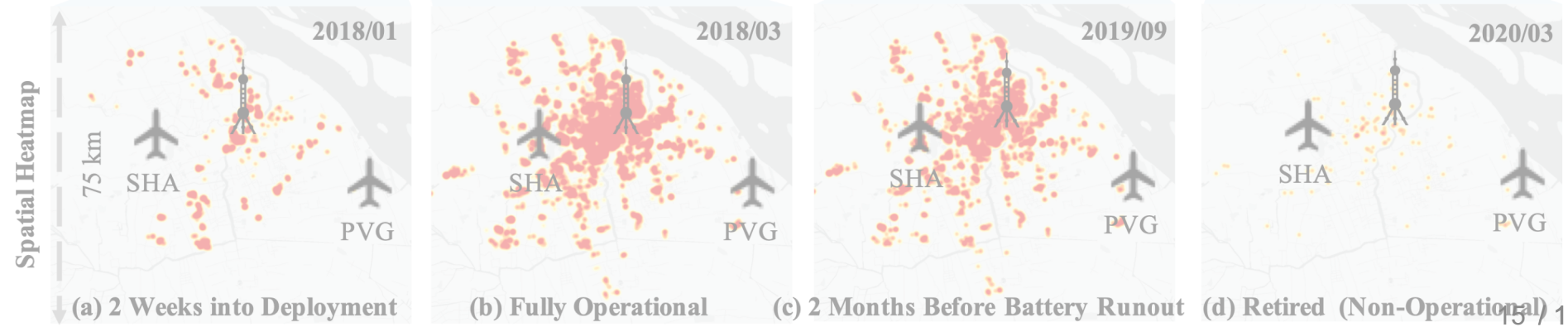
Data Size: 31,131 couriers at 2,466 shops in one month.



Permanent link: https://tianchi.aliyun.com/dataset/dataDetail?dataId=76359#

Thanks All Yi Ding dingx447@umn.edu, dy207346@alibaba-inc.com





References

[MobiSys 11] Tarzia, Stephen P., Peter A. Dinda, Robert P. Dick, and Gokhan Memik. "Indoor localization without infrastructure using the acoustic background spectrum." In *ACM MobiSys*, pp. 155-168. 2011.

[NSDI 13] Shen, Guobin, Zhuo Chen, Peichao Zhang, Thomas Moscibroda, and Yongguang Zhang. "Walkie-Markie: Indoor pathway mapping made easy." In *10th {USENIX} {NSDI} 13*, pp. 85-98. 2013.

[NSDI 15] Adib, Fadel, Zachary Kabelac, and Dina Katabi. "Multi-person localization via {RF} body reflections." In *12th {USENIX} ({NSDI} 15)*, pp. 279-292. 2015.

[NSDI 16] Vasisht, Deepak, Swarun Kumar, and Dina Katabi. "Decimeter-level localization with a single WiFi access point." In *13th {USENIX} ({NSDI} 16)*, pp. 165-178. 2016.

[MobiSys 2017] Wei, Yu-Lin, Chang-Jung Huang, Hsin-Mu Tsai, and Kate Ching-Ju Lin. "Celli: Indoor positioning using polarized sweeping light beams." In *ACM MobiSys*, pp. 136-147. 2017.

[IoT Journal 2018] Jeon, Kang Eun, James She, Perm Soonsawad, and Pai Chet Ng. "Ble beacons for internet of things applications: Survey, challenges, and opportunities." *IEEE Internet of Things Journal* 5, no. 2 (2018): 811-828.

[MobiCom 18] Lu, Chris Xiaoxuan, Yang Li, Peijun Zhao, Changhao Chen, Linhai Xie, Hongkai Wen, Rui Tan, and Niki Trigoni. "Simultaneous localization and mapping with power network electromagnetic field." In *ACM MobiCom* pp. 607-622. 2018.

[MobiSys 18-1] Shen, Sheng, Mahanth Gowda, and Romit Roy Choudhury. "Closing the gaps in inertial motion tracking." In *Proceedings of the 24th ACM MobiSys*, pp. 429-444. 2018.

[MobiSys 18-2] Tian, Zhao, Yu-Lin Wei, Wei-Nin Chang, Xi Xiong, Changxi Zheng, Hsin-Mu Tsai, Kate Ching-Ju Lin, and Xia Zhou. "Augmenting indoor inertial tracking with polarized light." In *ACM MobiSys*, pp. 362-375. 2018.