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BiCord: Bidirectional Coordination among Coexisting Wireless Devices

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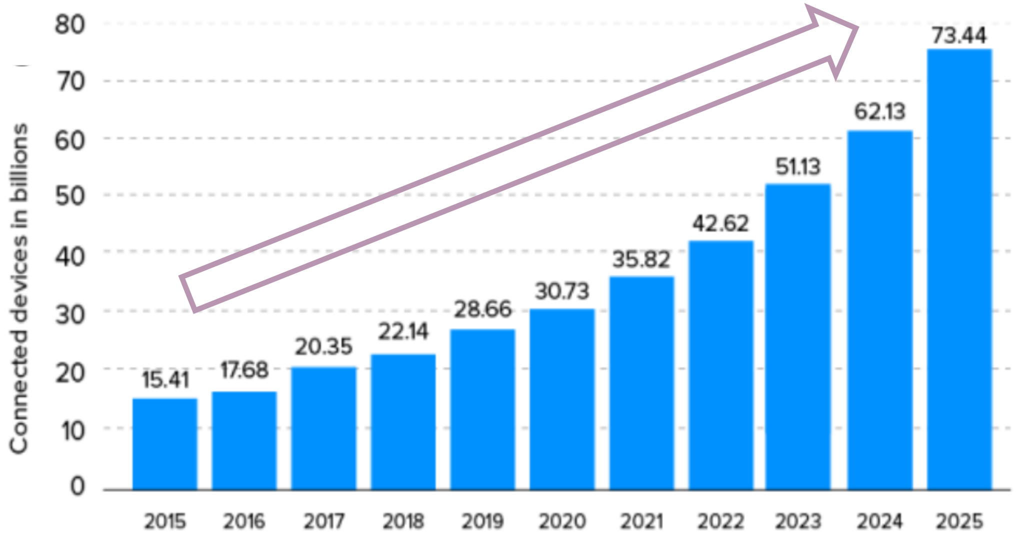
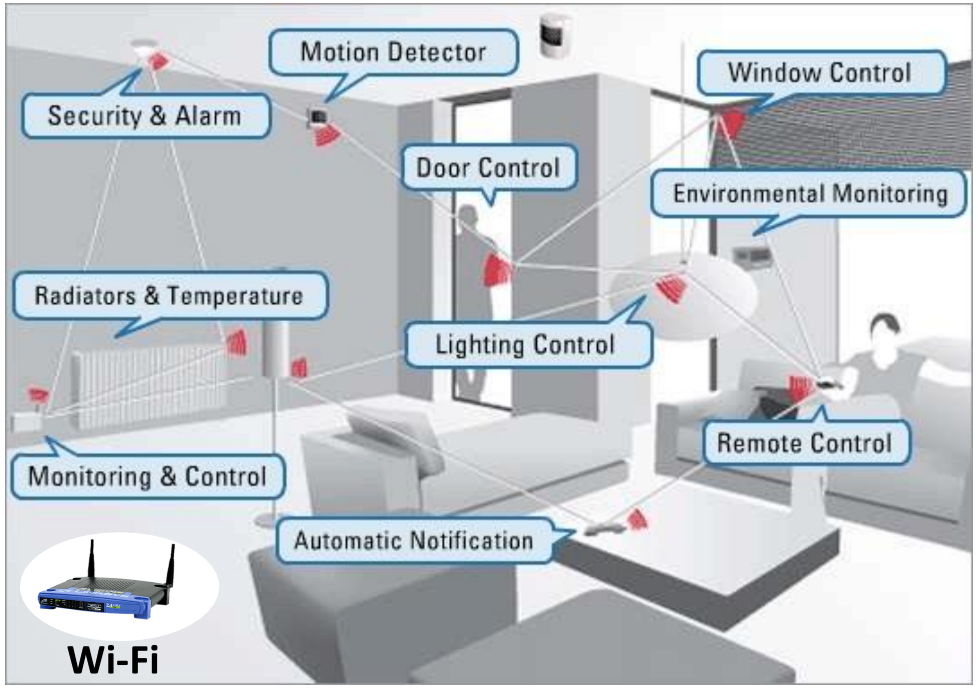
The rapid growth of the Internet of Things

Various types of technologies

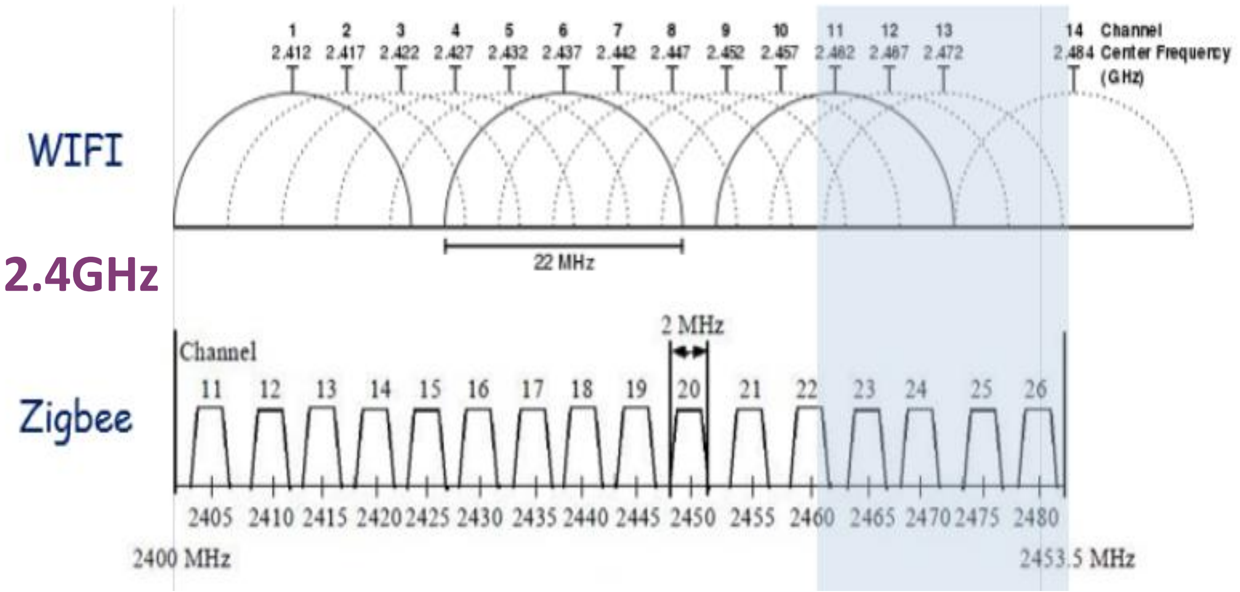


An increasing number of devices

Crowded ISM bands

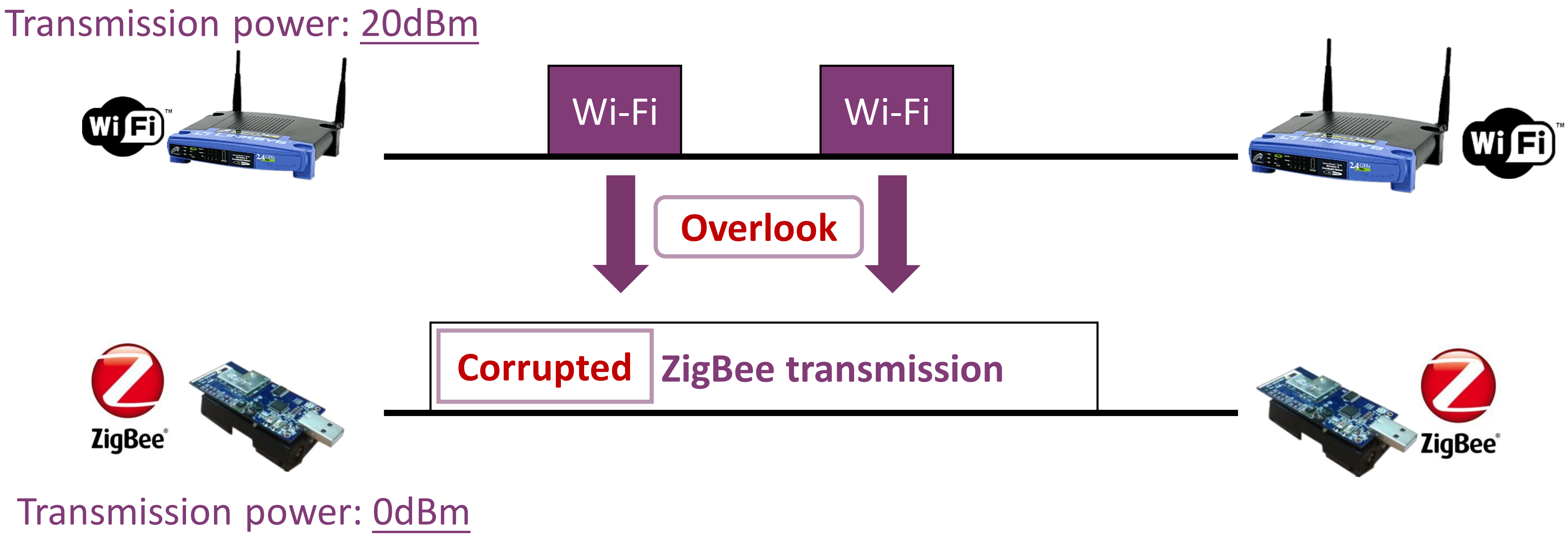


The coexistence of devices using different technologies



Devices of different technologies share the ISM bands

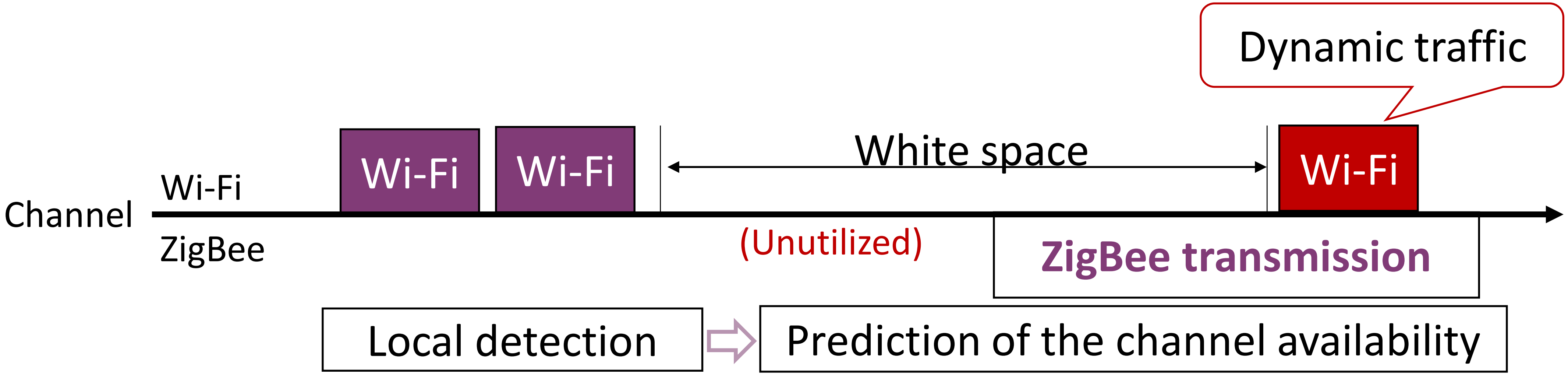
Cross-technology interference (CTI)



Low-power wireless device are vulnerable to cross-technology interference
An unfair channel allocation due to power asymmetry

Gauging channel availability?

WISE (ICNP 2010); Smoggy-Link (ICNP 2016)



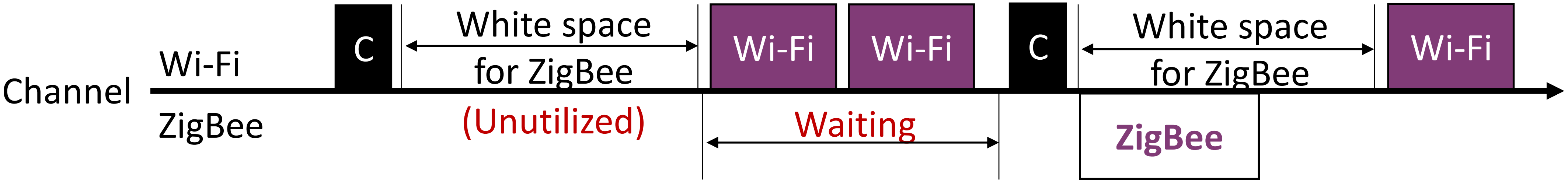
Low power devices suffer from dynamic interference

Poor channel utilization: white space not utilized

Unidirectional information transfer?

ECC (MobiSys 2018)

C Control packet of Wi-Fi



Unutilized channel resources: Wi-Fi does not know the requirements of ZigBee

Delay of low power devices: ZigBee waits for control packet from Wi-Fi

Need of bidirectional coordination

Problems to solve:

- **How to improve the performance of low power nodes in both packet delivery rate and transmission delay?**
- **How to maximize the availability of the spectrum?**

Design object of bidirectional coordination (BiCord):

- **To make low power nodes request and obtain channel resources in time**
- **On-demand channel allocation for low-power nodes**

Part I - Challenge

Challenge of bidirectional channel coordination

Lower power

Overlook

Higher power

ZigBee

How to inform the need?

Cross-technology communication techniques: **unsuitable!**

ZigFi (INFOCOM 2018), AdaComm (SECON 2019)

ZigBee

Synchronization process
(Barker code, 110ms)

Communication

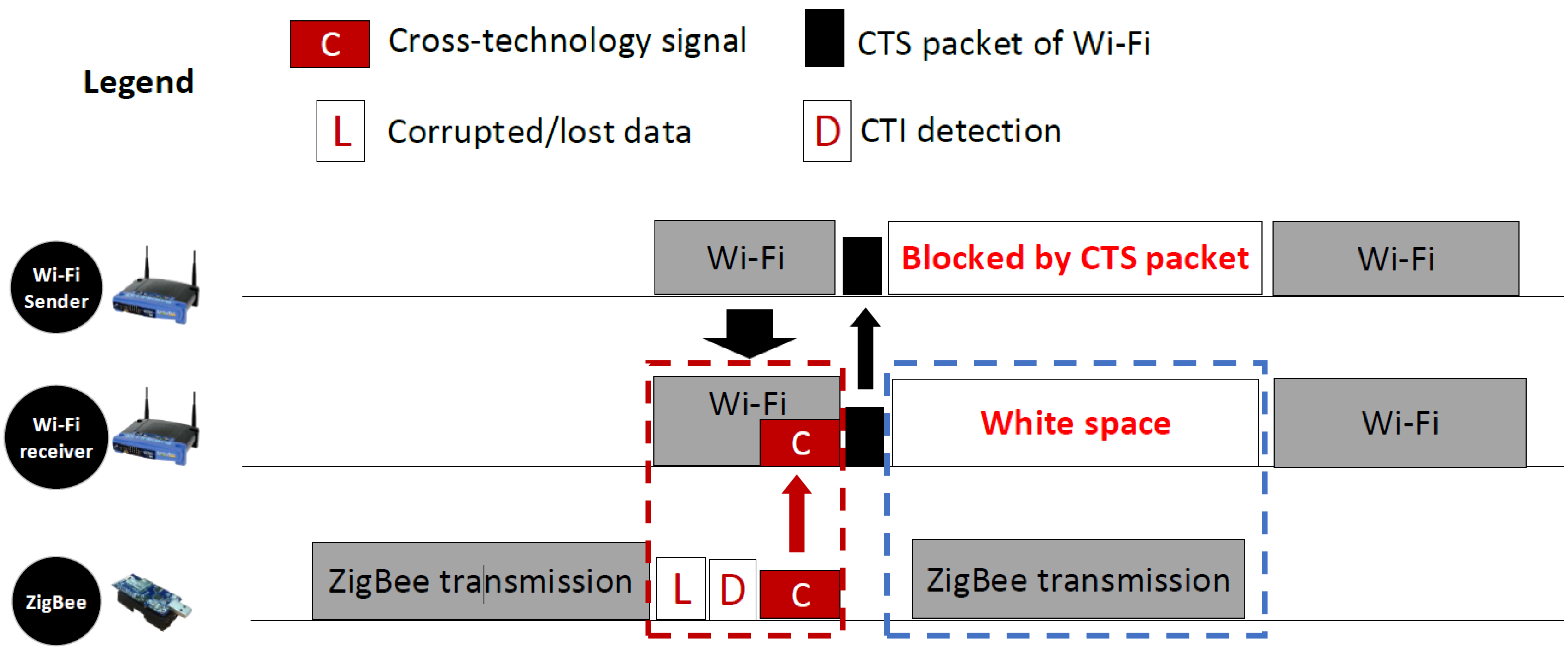
A typical transmission
Five 50-bytes packets (30ms)

ZigBee

To inform the need,
ZigBee only needs a **signal**!

Part II – BiCord Design

BiCord Overview

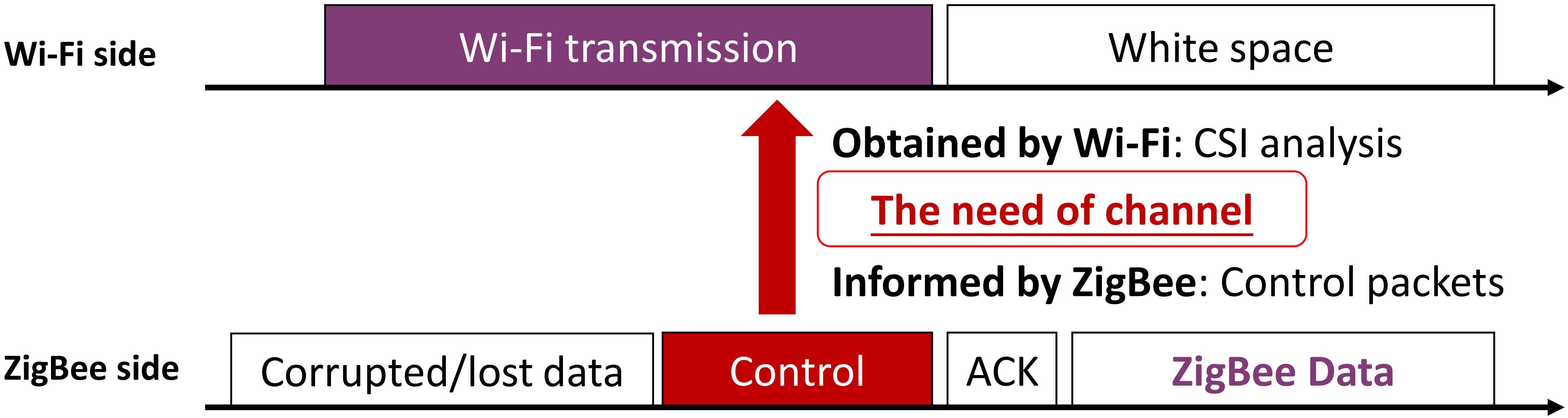


(i) Cross-technology signaling: ZigBee nodes directly inform **the need to access the channel**

(ii) Adaptive white space allocation: WiFi devices provide **on-demand channel allocation**

Cross-technology signaling

Workflow

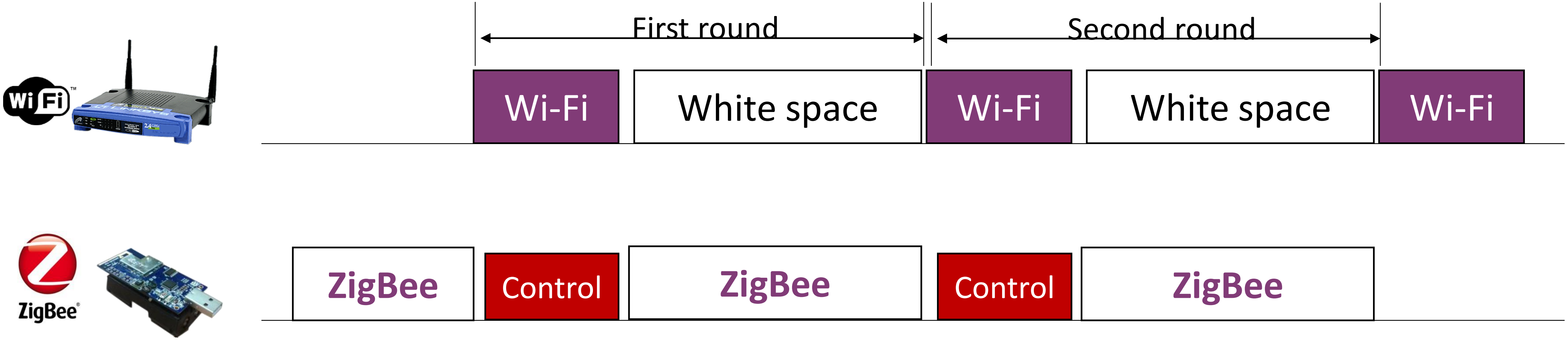


CSI analysis at Wi-Fi side:

To fully synchronize to ZigBee and decode its information ✗

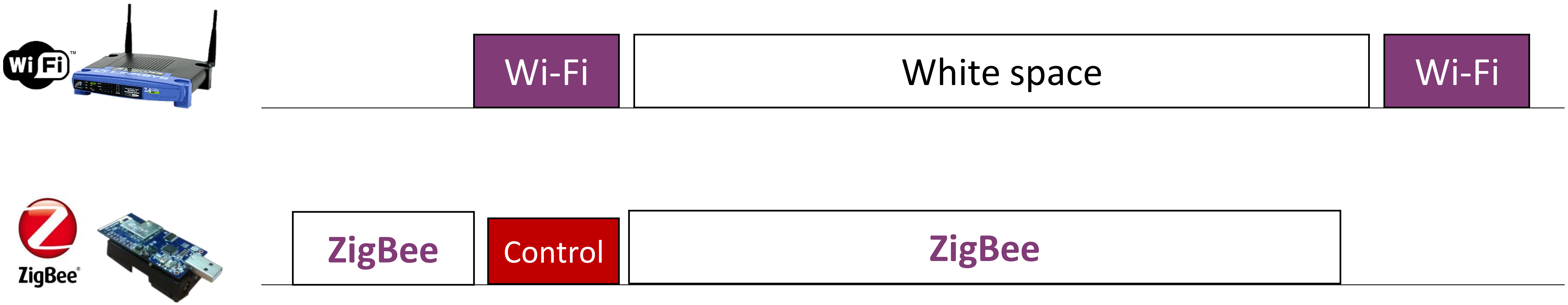
To detect the existence of a ZigBee transmission ✓

Adaptive white space allocation



First phase: Learning phase

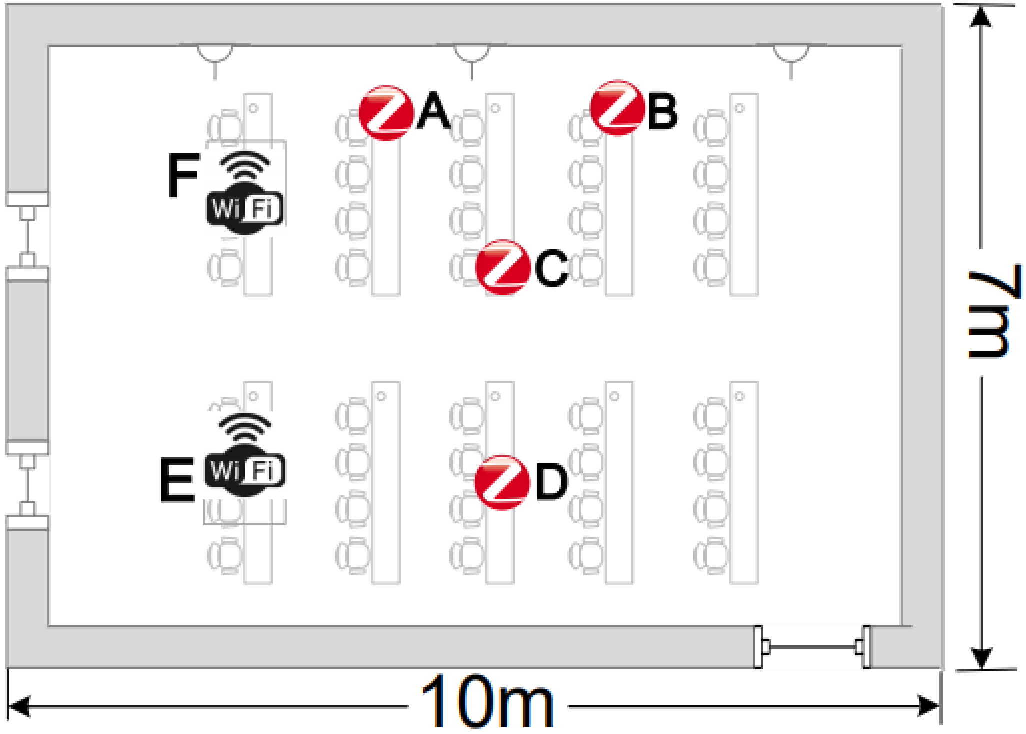
Adaptive white space allocation



Second phase: White space allocation

Part III – Evaluation

Evaluation Setup



- Commercial off-the-shelf Wi-Fi devices (Intel 5300 series) at location E and F
- Commercial ZigBee nodes (TelosB motes running Contiki 3.0) at location A-D

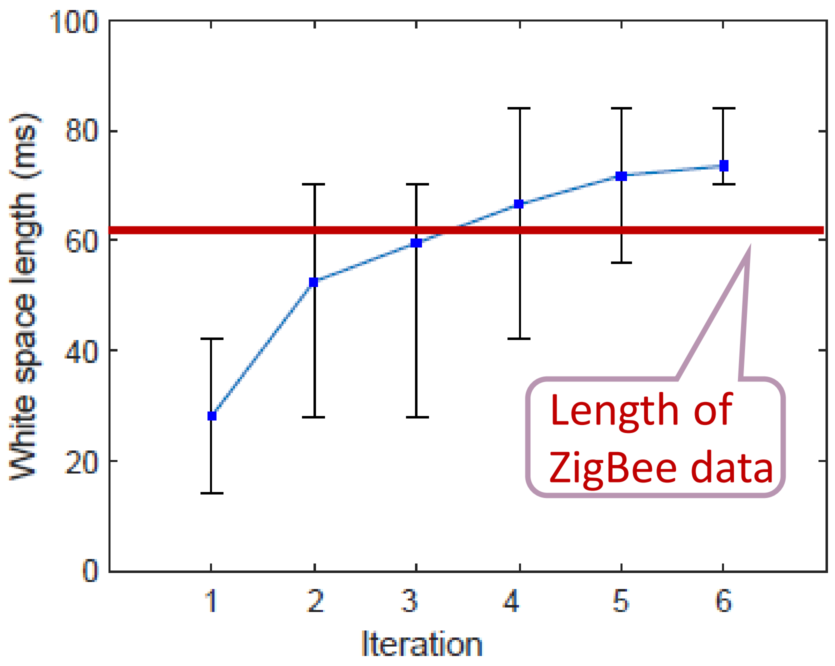
Evaluation: modules

TABLE I
THE PRECISION OF CROSS-TECHNOLOGY SIGNALING AT DIFFERENT LOCATION WITH DIFFERENT PARAMETERS.

Power (dBm)	0			-1			-3		
Packet Number	3	4	5	3	4	5	3	4	5
Location A	0.8548	0.9355	0.95	0.8533	0.93	0.9714	0.8286	0.9365	0.9525
Location B	0.8571	0.9057	0.9649	0.8	0.8333	0.9	0.7183	0.8571	0.9167
Location C	0.5862	0.7333	0.8	0.83	0.8636	0.9	0.72	0.8222	0.86
Location D	0.6125	0.71	0.73	0.7222	0.76	0.83	0.8	0.8636	0.91

TABLE II
THE RECALL OF CROSS-TECHNOLOGY SIGNALING AT DIFFERENT LOCATION WITH DIFFERENT PARAMETERS.

Power (dBm)	0			-1			-3		
Packet Number	3	4	5	3	4	5	3	4	5
Location A	0.88	0.9355	0.9828	0.8889	0.9538	0.9839	0.9155	0.9219	0.9825
Location B	0.7273	0.8955	0.8302	0.7727	0.8421	0.9483	0.62	0.7969	0.8182
Location C	0.73	0.7526	0.762	0.87	0.92	0.9	0.68	0.675	0.75
Location D	0.68	0.6383	0.67	0.63	0.7029	0.71	0.7358	0.78	0.82



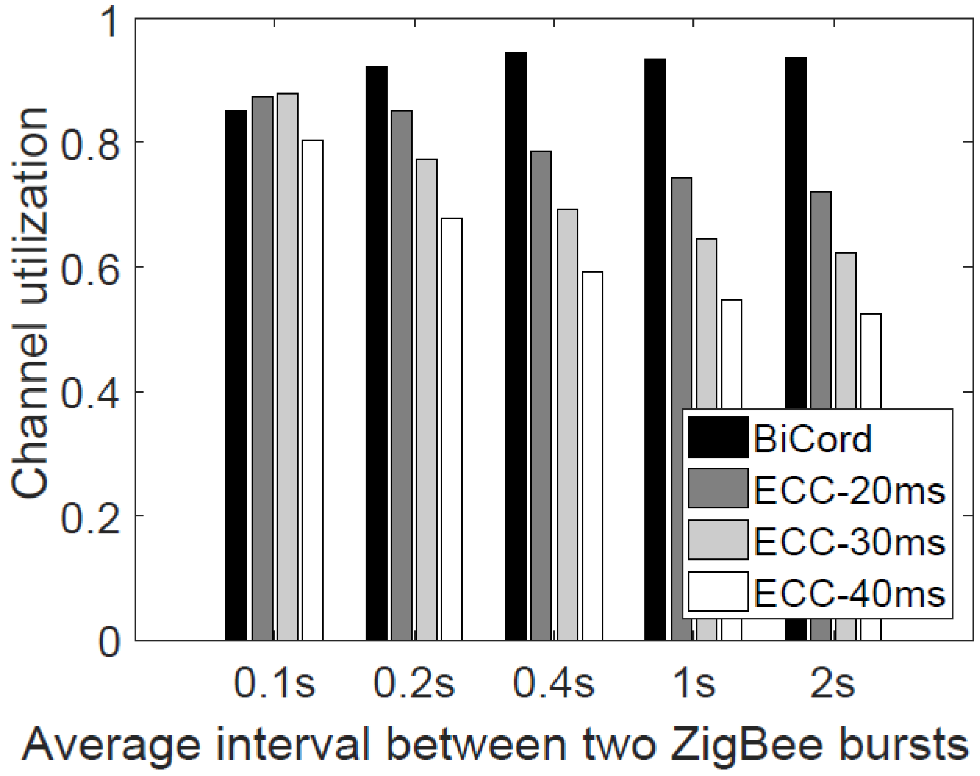
Cross-technology signaling:

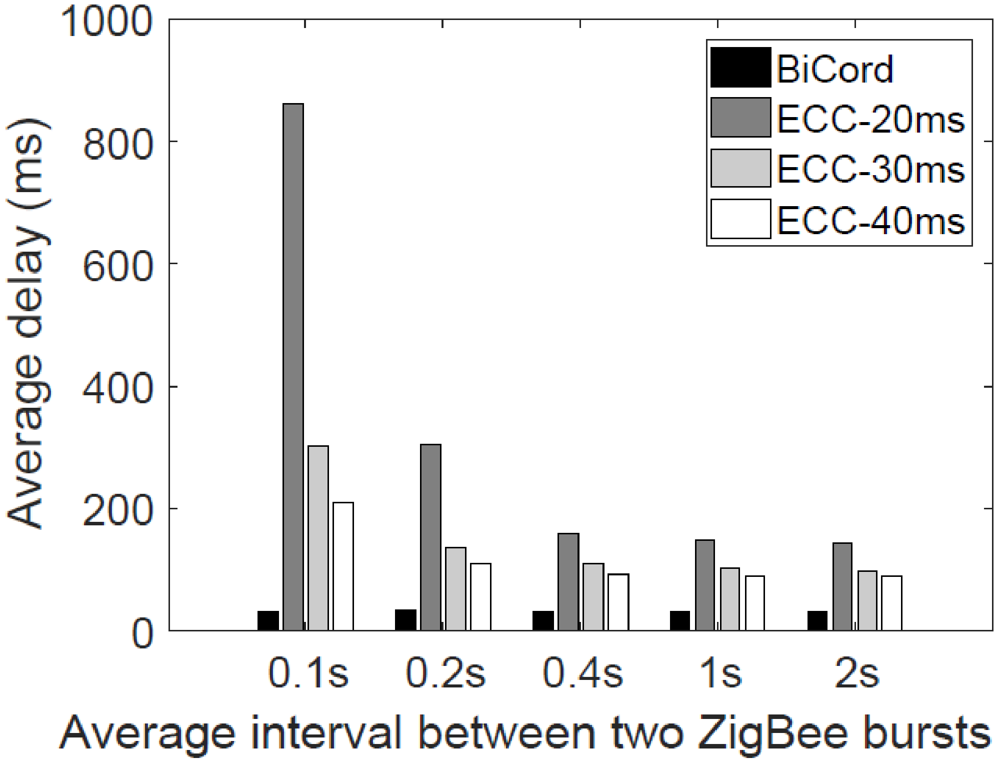
Precision of 90.6%; Recall of 92%.

Adaptive white space allocation:

5 iterations .

Evaluation: comparison with state-of-the-art approach





Channel utilization: BiCord is higher than ECC by 50.6%

Delay: BiCord outperforms ECC in average by 84.2%

Conclusion & Future Works

Conclusion:

- Need of channel coordination based on bidirectional interaction between constrained wireless devices (ZigBee) and more powerful appliances (Wi-Fi)
- Design of BiCord based on a cross-technology signaling method and an adaptive white space allocation scheme
- Evaluation of BiCord on commercial devices

Future Works:

- Extension to other coexistence scenarios

Thanks

Q & A

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http://tns.thss.tsinghua.edu.cn/sun/researches/InterferenceManagement.html