

Advanced Wireless Cooperation mechanisms for Interference Mitigation in the 2.4 GHz ISM Band

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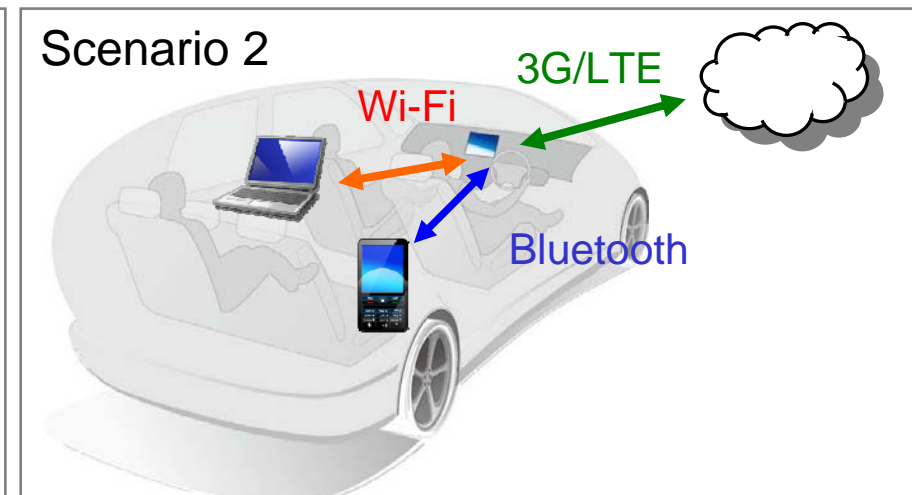
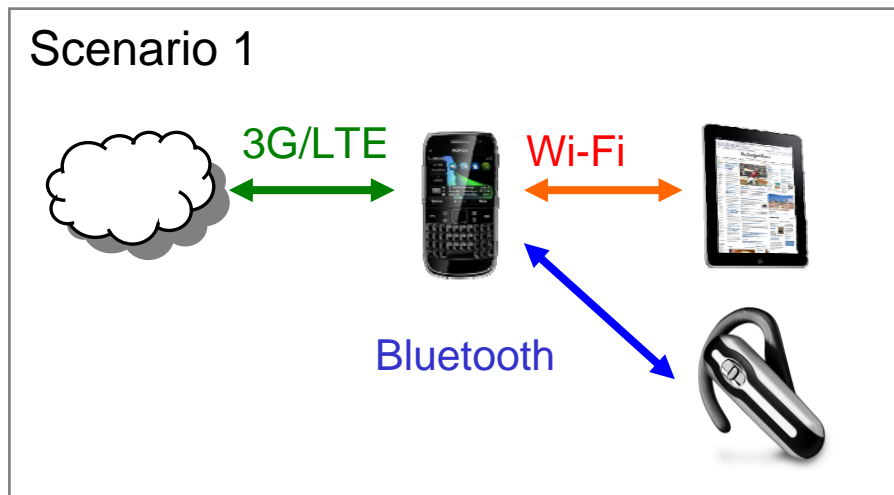
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Outline

- Background & Motivation
- Related Work & Problem Statement
- Our Proposal
- Simulation results and Prototyping
- Conclusion

Background

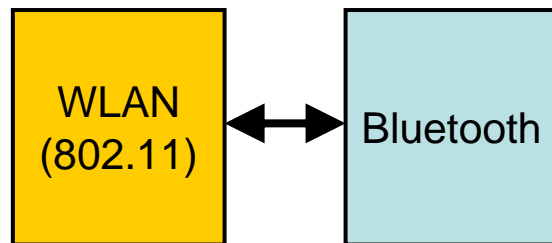
- As the variety of portable device applications has been increasing, portable devices such as smart phones, tablets and netbooks carry two or more kinds of wireless network interfaces.
- Requirement for Connected Car, Wi-Fi hotspot is installed on Navigation unit (a.k.a Head Unit) in addition to Bluetooth in the luxury Car.
- Bluetooth and IEEE802.11 are sometimes used simultaneously in mutually complementary use cases.
 - 1) Bluetooth is used for hands-free call while WLAN is used for internet connection
 - 2) Bluetooth is used for A2DP/HFP while WLAN is used for internet connection



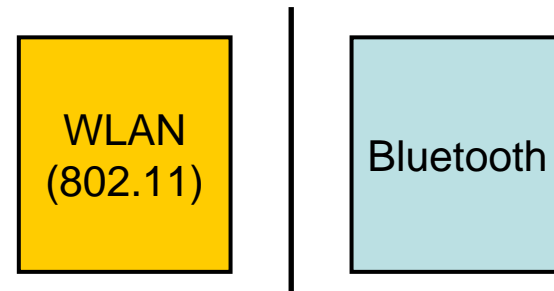
A2DP: Advanced Audio Distribution Profile, HFP: Hand-Free Profile

Related Work & Problem Statements

- The problem of coexistence and mutual interference between Bluetooth and WLAN has been well investigated.
- Coexistence mechanisms can be classified into two types according to their working principles:
 - ✓ **Collaborative mechanisms** : IEEE802.15.2, V-OLA etc
 - ✓ **Non-collaborative mechanisms** : Bluetooth AFH, etc



Collaborative



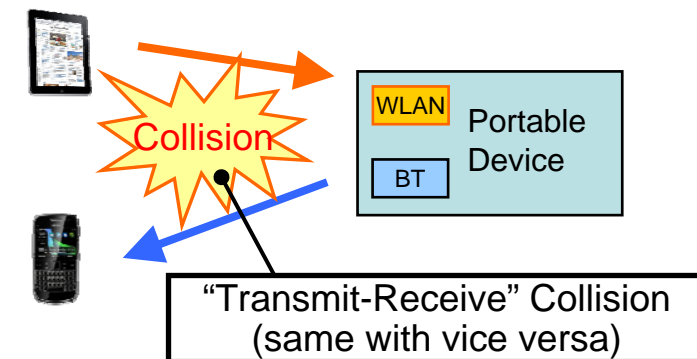
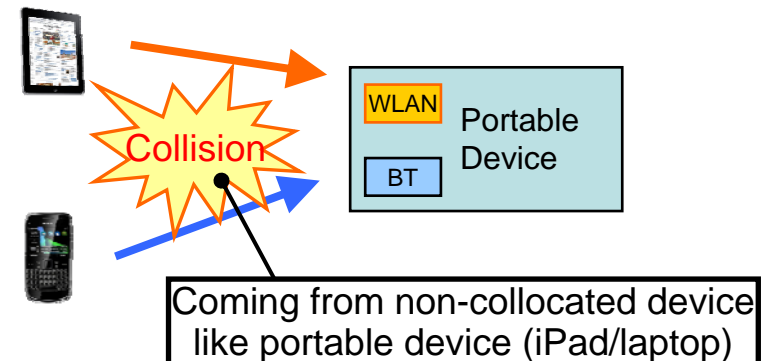
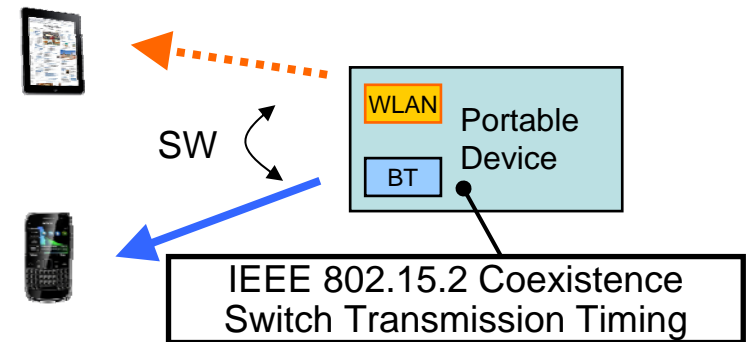
Non-collaborative

AFH: Adaptive Frequency Hopping, V-OLA: Voice-overlap avoidance (proposed by Carla F. [2])

Legacy: Collaborative Mechanisms

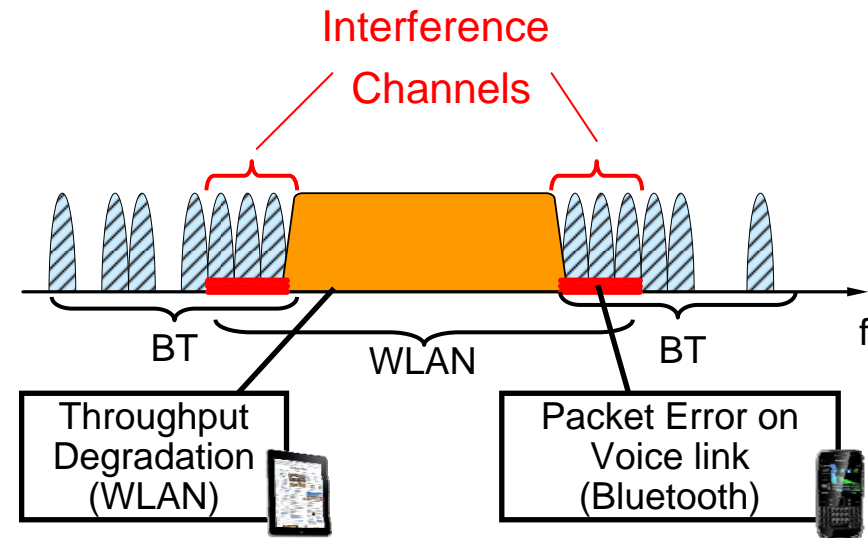
IEEE802.15.2 Coexistence:

- IEEE802.15.2 slightly reduces the ratio of collision rate between Bluetooth and WLAN, but DOESN'T improve performance for Bluetooth and WLAN.
- This mechanism is unable to mitigate interference coming from non-located devices.
- In the case of “Transmit-Receive” collisions which one radio is transmitting and the other is receiving, 802.15.2 Coex is also unable to mitigate interference.
- Furthermore, since they completely alternate transmissions of technologies sharing the same radio spectrum, the system throughput must be significantly degraded. (e.g. WLAN: 20+Mbps → 8Mbps while using Bluetooth HFP on measurements)



Bluetooth AFH:

- Bluetooth AFH improves Bluetooth performance, but the existed devices such as WLAN remain interference because only the channel condition of Bluetooth is considered.
- Bluetooth uses adjacent channels of WLAN operation channel which caused interference for WLAN throughput and small packets error of Bluetooth.
- Furthermore, Bluetooth and WLAN are set up in close, WLAN transmission is controlled because WLAN detects Bluetooth by the carrier sense in adjacent channel.
(e.g. WLAN: 20+Mbps → 19Mbps while using Bluetooth HFP on measurements)



Summary of Problem Statements

- As the mutually complementary use cases of Bluetooth and WLAN became popular, it was found that these interference avoidance functions do not work effectively.
- In some former investigations, methods to improve the efficiency of the interference avoidance were proposed.
- These former investigations, however, cannot avoid a kind of interference:
 - ✓ Throughput degradation due to alternative transmission (IEEE802.15.2)
 - ✓ “Transmit-Receive” collisions which one radio is transmitting and the other is receiving (IEEE802.15.2)
 - ✓ False detection by WLAN carrier sense because the interference avoidance mechanism of AFH considers only the channel condition of Bluetooth (Bluetooth AFH)

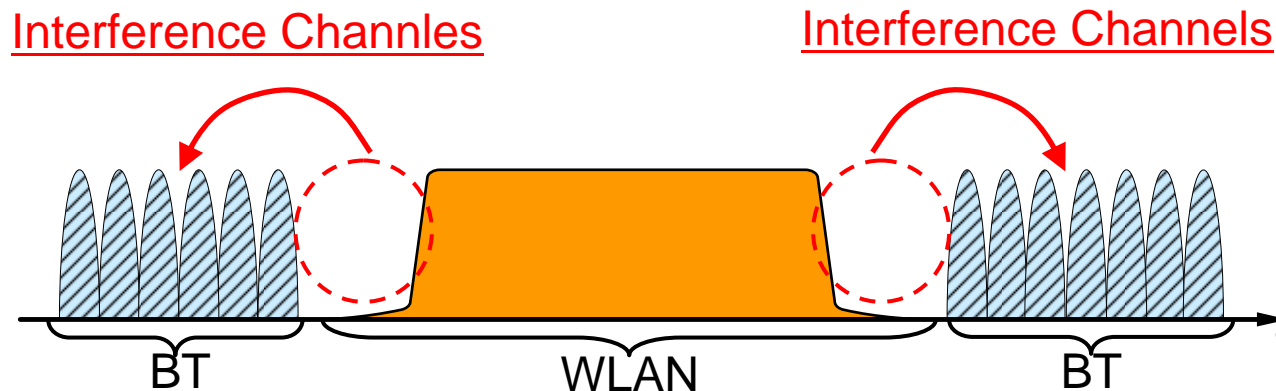
Our Motivation / Goal

- Both Interference mitigation and throughput improvement for Bluetooth & WLAN

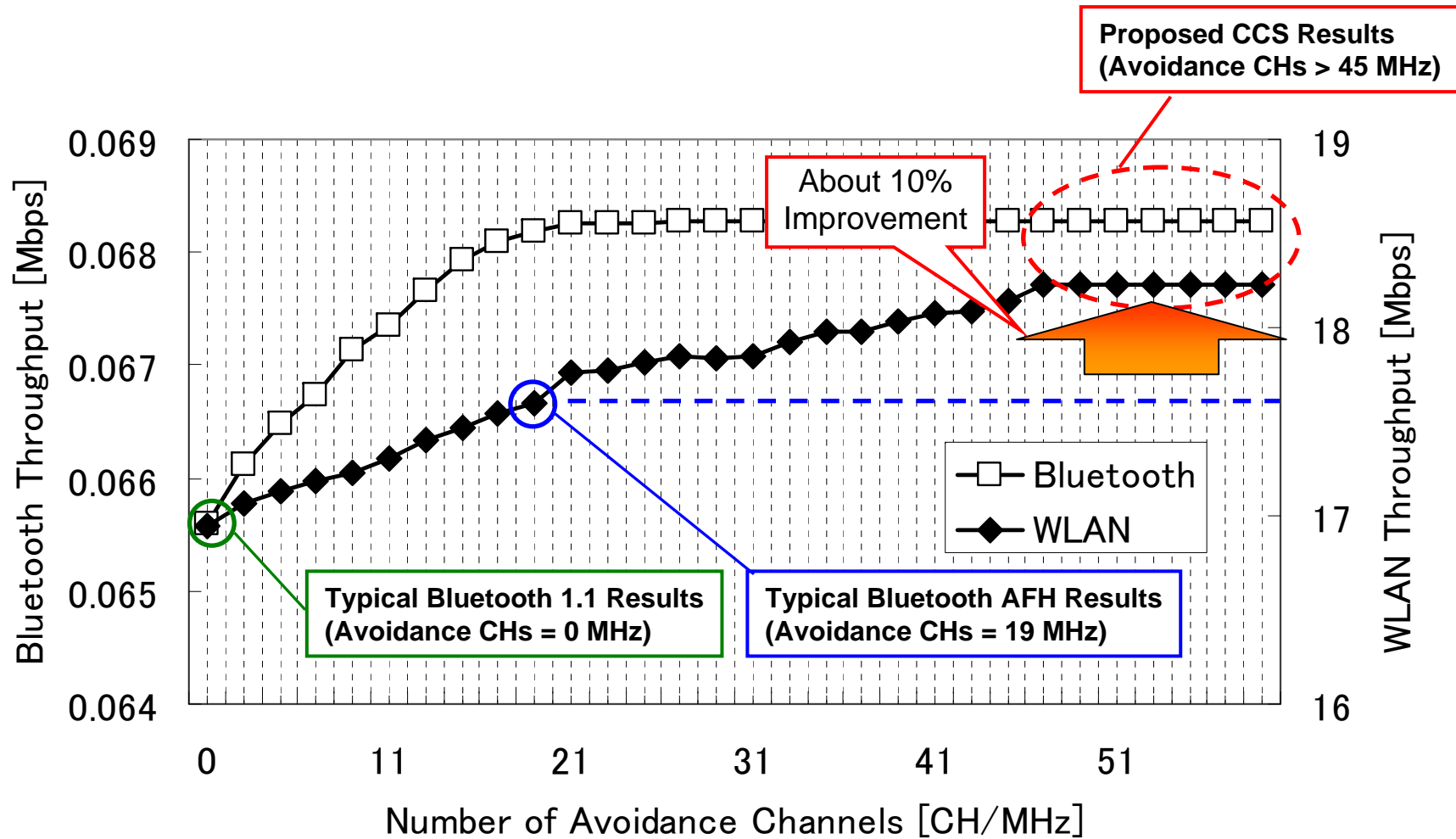
Advanced Wireless Cooperation Mechanisms: Cooperative Channel Segmentation (CCS)

Our Basic Concept :

- Enhances the current AFH mechanisms to avoid frequency overlap channels between Bluetooth and WLAN in consideration of mutual interferences and the carrier sense detection of WLAN.
- Shares the mutual interference channel information and divides operation channels between Bluetooth and WLAN at Driver SW.
- The proposed algorithm can apply when Bluetooth and WLAN are able to exchange information on the same portable device.



Simulation Results



Prototyping and Measurement Results

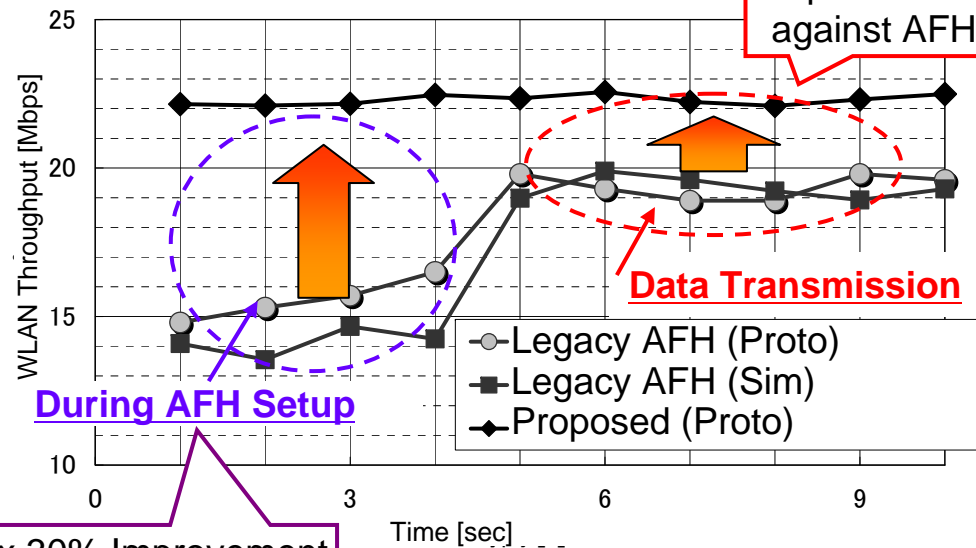
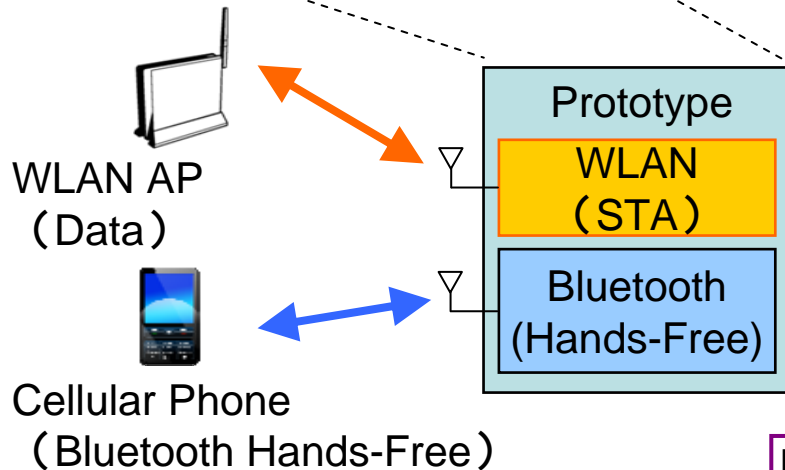
Comparison with Legacy mechanisms

- IEEE802.15.2 Coexistence : WLAN 8Mbps with noise on Bluetooth
- Legacy AFH : WLAN 19Mbps without noise on Bluetooth



Conditions

Prototype : Thinkpad X61+ Marvell SD8686 (BT/WLAN Combo)
 Bluetooth : 2.1 (AFH)
 WLAN : IEEE802.11g
 OS : Linux Kernel 2.6.28
 I/F : SDIO (BT, WLAN)
 Mode : BT (Master/Slave)、WLAN(STA)



Max 30% Improvement against AFH

Over 10% Improvement against AFH

Conclusion:

- Propose the Cooperative Channel Segmentation (CCS) which mitigate mutual interference and improve throughput.
- Effectively avoids the false detection of WLAN carrier sense by considering pre-shared information of mutual interference channels.
- Results show over 10 % improvement for WLAN throughput against Legacy AFH, and achieve error free for Bluetooth caused by interference.
(250% improvement against IEEE802.15.2)

Work in progress and future works:

- Evaluations for other Bluetooth profile (A2DP, Wide-band Speech, etc)
- Evaluations in consideration with OBSS conditions, antenna correlation, WLAN/Bluetooth location.
- Implement this algorithm on Android Phones, embedded systems and products.

Thank you !