

Uplink multi-user transmission

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Introduction

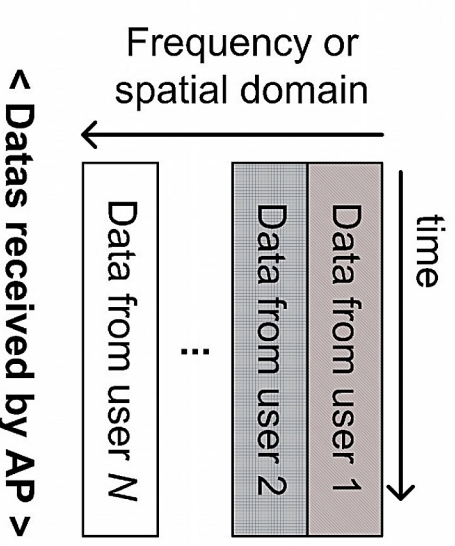
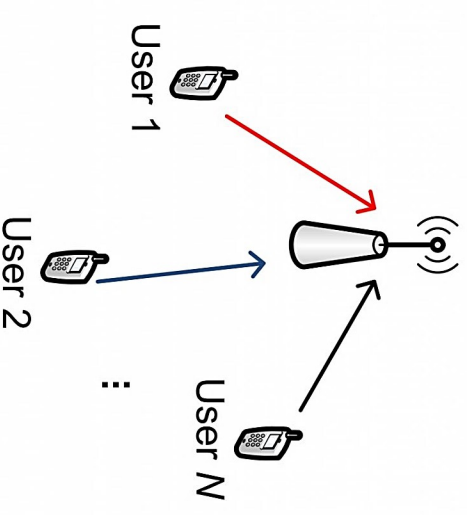
- **HEW considers high density of STAs in indoor and outdoor [1]. And uplink traffic will proliferate.**
 - Many users will use real-time video sharing, cloud service, etc
 - Large amounts of uplink feedbacks will be transmitted more frequently for enhancing resource efficiency
- **UL multi-user transmission can be an approach to achieve uplink efficiency enhancement by**
 - Efficient resource utilization
 - Reducing number of contentions
 - Reducing overhead for back-off time, polling, etc.
- **In this contribution, we check the PHY and MAC feasibility of UL multi-user transmission.**

Agenda

- **UL MU transmission**
 - Concept
 - Categorization by Multiplexing types
 - Categorization by Data types
- **PHY feasibility check by multiplexing types**
 - In view of time difference
 - In view of frequency difference
 - In view of received power difference
- **MAC feasibility check by data types**
 - In view of MAC overhead
- **Conclusion**

UL Multi-User Transmission

- **Concept**
 - Users transmit their data to a AP at the same time.
- **Categorization by Multiplexing Types**
 - Frequency Domain Multiplexing (FDM)
 - E.g. OFDMA in a channel or in multiple channels [2][3]
 - Spatial Domain Multiplexing (SDM)
 - E.g. UL MU MIMO [4]
 - Code Domain Multiplexing (CDM)
 - E.g. UL feedback in cellular network such as 3GPP LTE



UL Multi-User Transmission

- **Categorization by Data types**
 - Stand-alone UL frame
 - UL data frames are transmitted alone by some rule or indication by AP
 - DL-dependant UL frame
 - UL data frames are transmitted right after DL frame
 - e.g. UL control data corresponding to the DL data transmission

PHY Feasibility Check (Timing)

- **AP receives UL data from users with different arrival timing.**
 - Requirement
 - If CP length is sufficiently greater than channel delay plus time difference, then performance is not degraded by UL multi-user transmission.
 - Analyzed values
 - Channel delay: Maximum access delay of 95% users [Appendix, 5]
 - Max. time difference by round trip delay: max round trip delay – min round trip delay (*0nsec*)

	Indoor	Outdoor
Max. distance [6]	60 meters from 3 rd AP	130 meters from AP
Channel delay	58 <i>nsec</i>	800 <i>nsec</i> in UMi channel 1430 <i>nsec</i> in UMa channel
Max. round trip delay	400 <i>nsec</i>	833 <i>nsec</i>
Time difference	458 <i>nsec</i>	1633 <i>nsec</i> ~ 2263 <i>nsec</i>

PHY Feasibility Check (Timing)

→ Observation

- In indoor, UL MU transmission is possible with the current CP length (800ns).
- In outdoor, UL MU transmission is possible with the CP extension. And time compensation scheme such as transmission timing adjustment may be considered as well.
- According to the simulation results in contribution [4], UL MU MIMO is possible with 400ns CP length in indoor.

PHY Feasibility Check (Frequency)

- **AP receives UL data from users with different frequency offset.**
 - In 11ac spec requirement
 - 22.3.18.3: “The symbol clock frequency and transmit center frequency tolerance shall be ± 20 ppm maximum.”
 - : Frequency Offset is 30.72% and 64% of the subcarrier spacing at 2.4GHz and 5GHz, respectively.
 - In LTE spec requirement [7]
 - Minimum requirement of Frequency error is $\pm 0.05 \sim 0.25$ ppm and subcarrier spacing is 15kHz.
 - : Frequency Offset is 1.3% $\sim$ 6.7% of the subcarrier spacing at 2GHz.

PHY Feasibility Check (Frequency)

→ Observation

- In view of multiplexing types,
 - In FDM multiplexing case, UL MU transmission can be possible with simple compensation scheme such as guard subcarriers among UL data.
 - In SDM/CDM multiplexing case, compensation scheme such as frequency offset adjustment or tighter requirement is needed.
- The requirement of ± 20 ppm is used from 11a specification. Now we have to consider the realistic requirement.
- According to the simulation results in contribution [4], UL MU MIMO is well performed within 4kHz difference. It means that frequency offset has to be under ± 1 ppm.

PHY Feasibility Check (Power)

- **AP receives UL data from users with different rx power.**
 - Power difference causes performance degradation due to quantization problem by AGC. That's more critical in the case of SDM and CDM than in the case of FDM because UL data may be separated in frequency domain before quantization in FDM.
 - Path loss among users served by a AP

	InH LoS	InH NLoS	UMi LoS	UMi NLoS
Distance [6]	3~12meter	3~60meter	10~130meter	10~130meter
PL (dB) [8]	48.47 ~ 58.64	39.76 ~ 90.10	57.6 ~ 82.11	69.29 ~ 110.17

PHY Feasibility Check (Power)

→ Observation

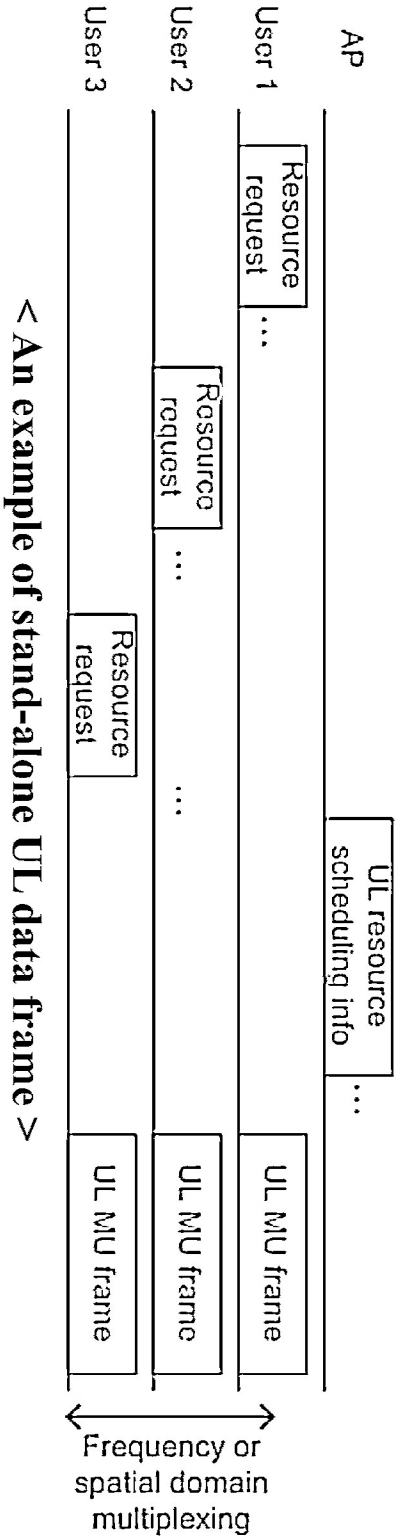
- UL MU transmission may be possible in FDM case by doing quantization in user's own band.
- But some schemes to compensate the difference or to make a UL MU group among users with similar rx power level are needed, especially, in SDM and CDM cases.
- According to the simulation results in contribution [4], there are 0.5 / 1 / 1.5dB loss of PER in users with the weaker power when AP receives UL data with 4 / 6 / 8dB power difference.

Summary of PHY Feasibility Check

	FDM	SDM, CDM
Timing difference	In indoor, feasible with the current CP In outdoor, infeasible now. Need CP extension, etc	
Frequency difference	Feasible with guard subcarriers between users	Infeasible with the current requirement of frequency offset . Need tighter requirement, etc
Power difference	Feasible with division in frequency	Infeasible due to quantization error

MAC Feasibility Check

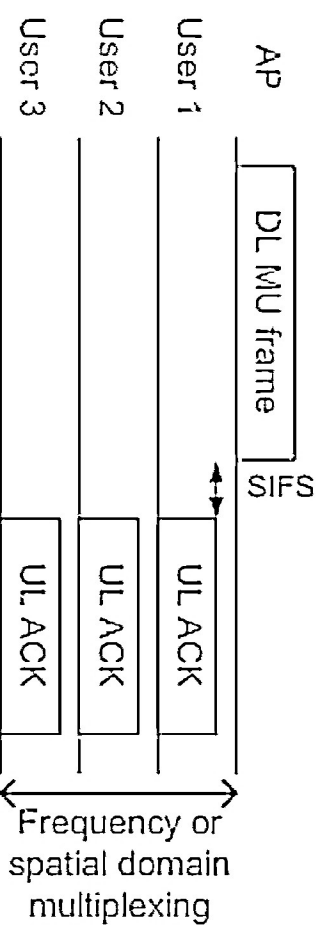
- **Check the feasibility in view of MAC overhead by data types**
- **Stand-alone UL data frame**
 - Users have to know transmission timing and the resource to transmit UL MU data. Then AP has to indicate the scheduling information before UL MU transmission. In order to do that, AP has to gather some information like UL data type/amount.
 - UL periodic data such as VoIP packet may be easily known next transmission timing, data amount, etc. And because usually VoIP packet is quite short, it may get more overhead reduction gain.



MAC Feasibility Check

● DL-dependant UL frame

- Users already know the transmission timing and resource because UL data followed by DL transmission. The DL transmission contains UL scheduling information implicitly or explicitly.
- Therefore there is little scheduling overhead. But the usage is limited.
 - e.g. UL MU ACK in response of DL-MU-MIMO frame
 - e.g. UL MU Sounding in response of DL NDP frame



< An example of DL-dependant UL frame >

Summary of MAC Feasibility Check

	Stand-alone UL data frame	DL-dependant UL frame
Delay	Can't guarantee transmission time (contention-based channel)	Right after SIFS + DL frame (no contention channel)
MAC overhead	Need new DL & UL control frames - UL BW request frame - DL scheduling frame	little overhead - Just follow the rule of DL frame - Add some signaling field in DL frame
Usage	All UL data frames	Limited. (DL-dependant UL frame only)

Conclusion

- **UL MU transmission is a method for UL efficiency enhancement**
- **PHY feasibility check**
 - It's possible in view of timing offset in indoor, not in outdoor.
 - UL MU FDM is feasible in the current requirement
 - UL MU CDM/SDM may need some schemes to compensate frequency offset, and power difference.
- **MAC feasibility check**
 - DL-dependant UL transmission is more feasible than stand-alone UL transmission due to some scheduling issue, etc.

Reference

- [1] 11-13-0657-06 HEW SG Usage models and requirements liaison with WFA
- [2] 11-09-0138-03 OFDMA Related Issues in VHTL6
- [3] 11-10-0317-01 DL-OFDMA for Mixed Clients
- [4] 11-09-1036-00 Uplink MU-MIMO Sensitivity to Power Differences and Synchronization Errors
- [5] 11-13-0536-00 HEW SG PHY Considerations For Outdoor Environment
- [6] 11-13-1001-03 HEW Simulation scenarios document
- [7] 3GPP TS 36.104 V12.1.0 E-UTRA Base Station radio transmission and reception (Release 12)
- [8] Report ITU-R M.2135-1(12/2009)

Appendix

- Simulation conditions are same in [5].

