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Advanced MAC layer aspects for LiFi

Enabling LiFi for the Internet of Things

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Enabling LiFi for the Internet of Things: advanced MAC layer aspects

Outline

- Internet of Things communication architecture
- Operational aspects
- Medium Access Control principles
- MAC control functions
- MAC functions for multi access point infrastructures
- Lower layer mobility support for small cells
- IEEE 802.11 MAC for LiFi
- LiFi supporting MAC enhancements in IEEE 802.11ax
- Summary and conclusion

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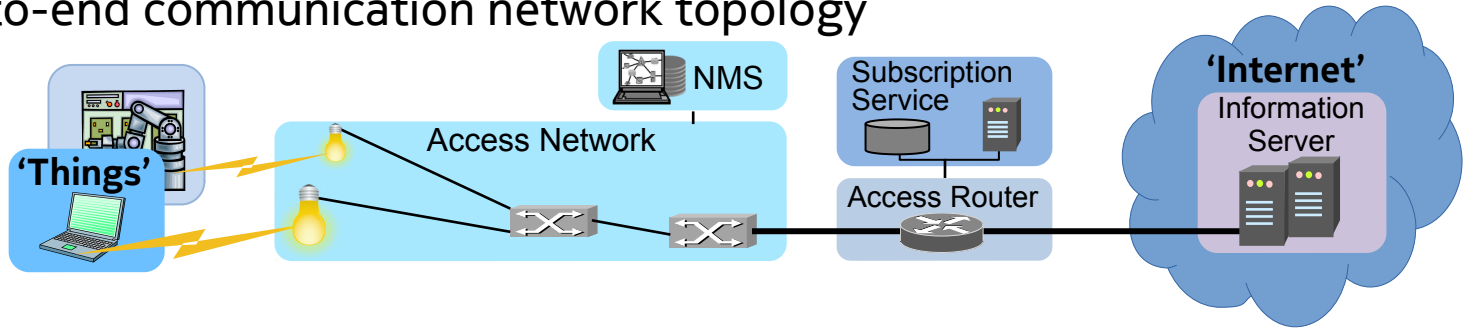
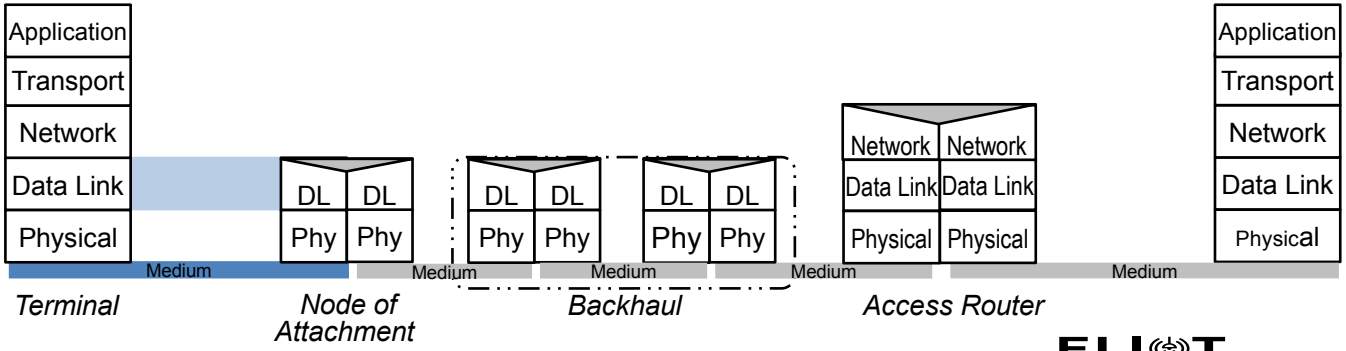
Internet of Things communication architecture

Things are getting connected to the cloud for the realization of services

End-to-end communication network topology



Protocol layer architecture



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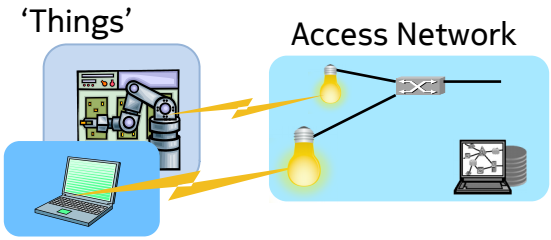
Operational aspects

LiFi has to cope with a shared medium

- When the communication peers of ‘things’ are located in the Internet, applications usually work well with best effort transmissions.
- The ‘things’ may move around at their locations.



- Multiple access points might be needed to cover the operational domain.
- Likely, there is more than one ‘thing’ served by a single access point.
- The access points of an operational domain build an access network.
  - Some kind of common control and management is available.
- Light is a shared medium.
  - Light sources might overlap.
  - ‘Uncoordinated’ light sources may interfere with the domain.

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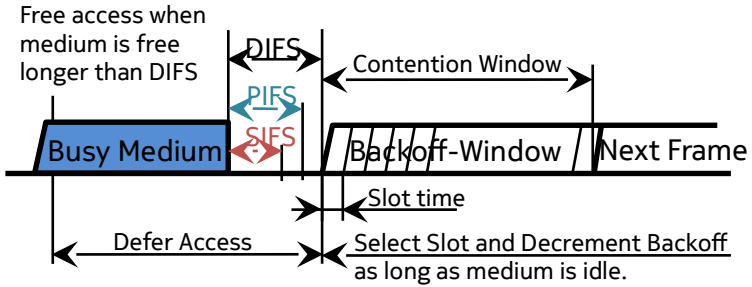
Medium Access Control principles
Distributed vs. centrally controlled

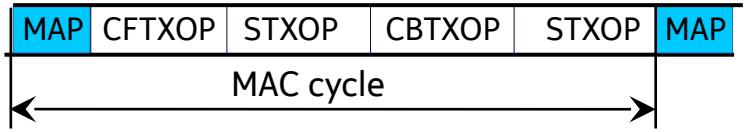
Carrier Sense Multiple Access



- Stations claim medium access through clear channel assessment procedure with random backoff periods.
- It works reasonably well under load but introduces unpredictable delays when congestion occurs.
- Well suited in uncoordinated environments

MAP controlled medium access

- Central controller assigns TXOPs in MAP (Medium Access Plan)



- Transmission Opportunities (TXOPs) are requested in Contention Based slots.
- Domain controller provide TXOP assignments in periodic MAP information element.
- Controller assumes full ownership of the medium.
- Highly efficient even under heavy load
- Not feasible in uncoordinated environments

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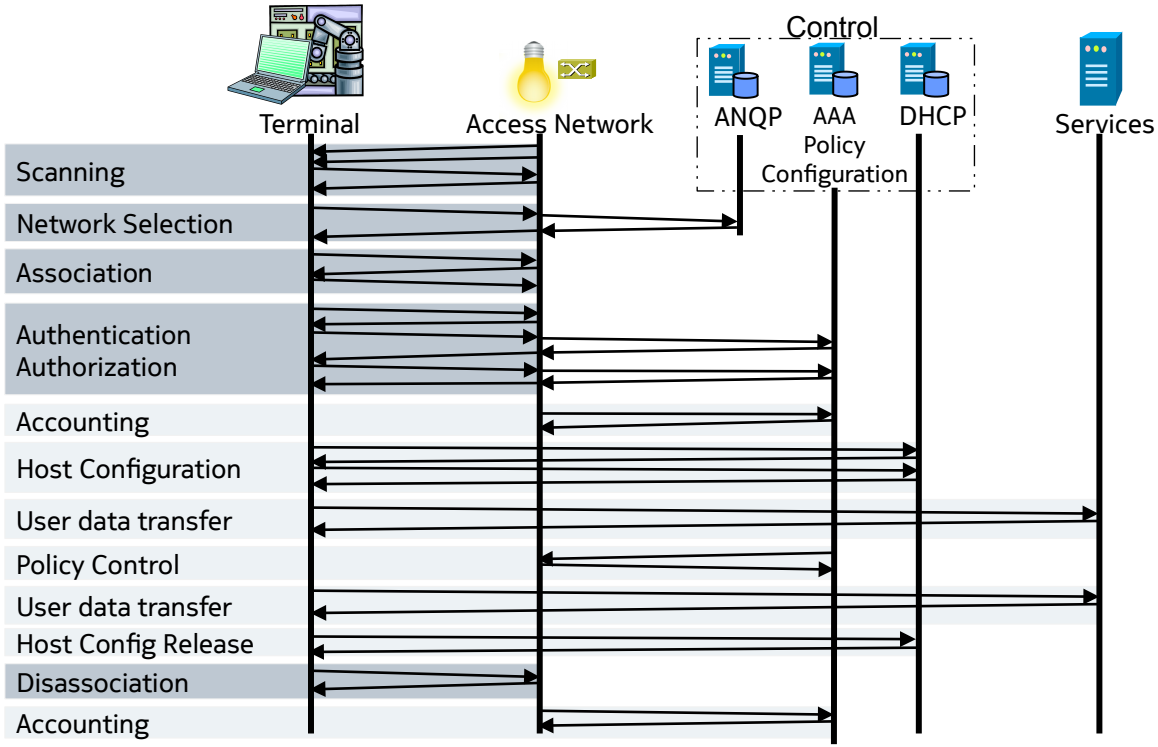
MAC control functions

Link establishment, maintenance, and teardown belong to MAC layer functions



- Mobile terminals use MAC control functions to discover and select access points.
- A data link is established through association and released through disassociation.
- As IP connectivity is terminated in the Internet, authentication and authorization is performed in the data link layer to allow for local control and administration.

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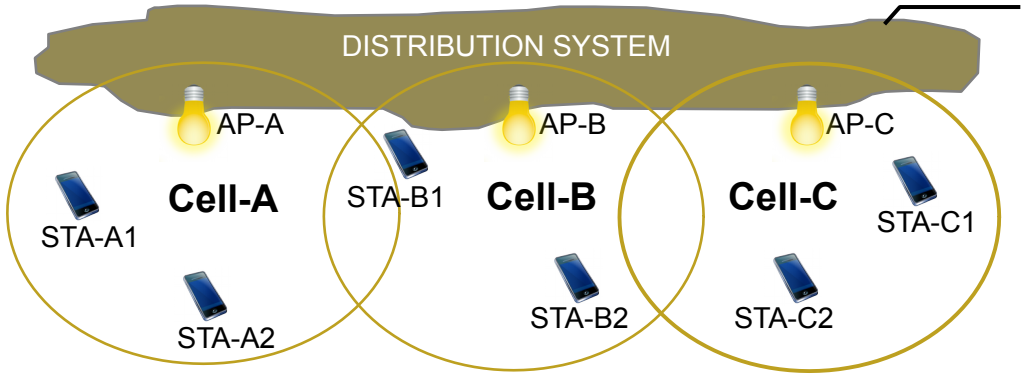
MAC functions for multi access point infrastructures

Multiple cells allow for increased coverage and throughput



- Multi-cell operation requires additional MAC signaling to enable end-to-end communication through a particular access point.
- Stations have to select their serving access point in the association procedure.
- Moving from one access point to another access point requires special MAC messaging as well as support in the distribution system to redirect user data frames to the new serving access point.
- To increase throughput, each of the cells have to establish a separate communication channel.

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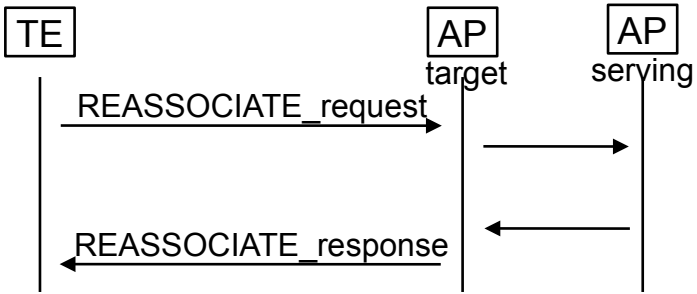
Lower layer mobility support for small cells

Re-association function enables MAC layer handover



- In uncoordinated environments, terminals usually initiate handovers.
- When a terminal determines that link quality suffers, it initiates scanning and search for a better access point.
- Once it concludes on the target AP, it sends a REASSOCIATE_request with reference to the previous serving AP.
- The target AP retrieves session information from the previous serving AP and answers the terminal with an REASSOCIATE_response when the link is to be relocated. The routing in the Ethernet backhaul is reconfigured through sending an Layer2-update frame upstream, which adjusts the forwarding tables in the bridges.
- Fast transition is possible when keying material has been cached previously, otherwise re-authentication is necessary.

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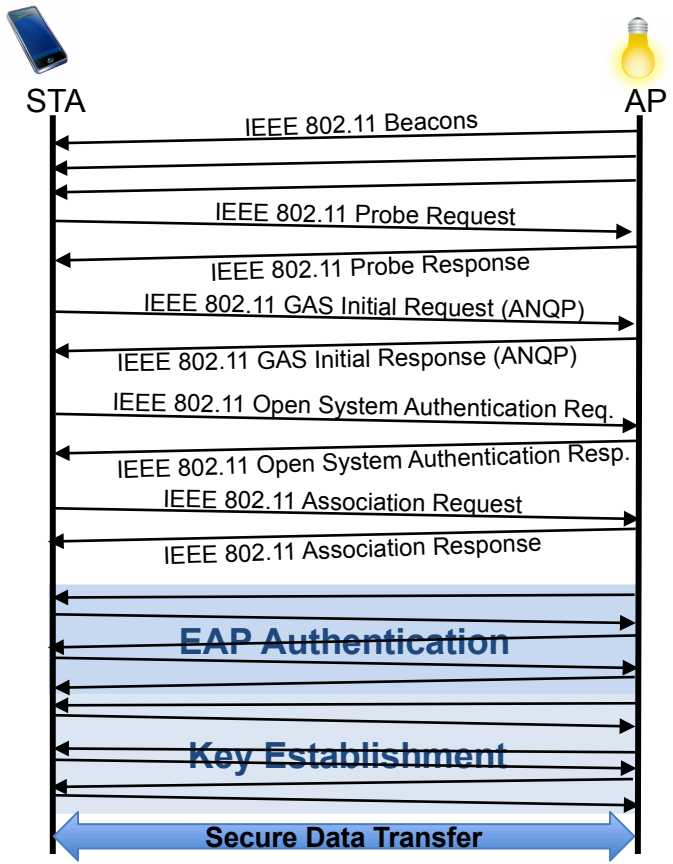
IEEE 802.11 MAC for LiFi



- The IEEE 802.11 MAC is suited for LiFi
  - CSMA/CA for coping with uncoordinated systems
  - All the necessary MAC functions for mobile operation of terminals
  - Rich support for authentication and on-boarding
  - Data Link layer mobility support with handover support through Ethernet switches
  - Fast Transition through pre-establishment/ caching of session credentials
  - Power save functions
- MAC enhancements of IEEE 802.11ax are also beneficial for LiFi.

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LiFi supporting MAC enhancements in IEEE 802.11ax

MAC enhancements increase performance in dense deployments

Feature	pre-IEEE 802.11ax	802.11ax
OFDMA	Not available	AP controlled medium access with dynamic assignment of 26, 52, 106, 242, 484, or 996 tones per station. Each tone consists of a single subcarrier of 78.125 kHz bandwidth. Therefore, bandwidth of a single OFDMA transmission is between 2.03125 MHz and ca. 80 MHz.
Multi-user MIMO (MU-MIMO)	Available in downlink direction	Available in downlink and uplink direction
Trigger-based Random Access	Not available	Allows performing UL OFDMA transmissions by stations which are not allocated RUs directly.
Spatial frequency reuse	Not available	Coloring enables devices to differentiate transmissions in their own BSS from transmissions in neighboring BSSs. Adaptive Power and Sensitivity Thresholds allow for dynamically adjusting transmit power and signal detection threshold to increase spatial reuse.
NAV	Single NAV	Two NAVs
Target Wait Time (TWT)	Not available	TWT reduces power consumption and medium access contention.

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Advanced MAC layer aspects for LiFi
Summary and conclusion

- LiFi has specific challenges for its MAC layer
  - Very small cells with lots of inter-cell interference
  - No channelization in the PHY
- LiFi requires a modern, mobile enabled, CSMA based MAC
- The IEEE 802.11ax MAC might be the best current model for the LiFi MAC
  - As adopted in IEEE P802.11bb
- Further research required for aggregated throughput enhancements in ultra-dense deployments
- Open question: ultra-low-latency communications w/ LiFi

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Thank you for your attention!
Questions, comments?

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