Komondor

An event-based IEEE 802.11ax WLANs Simulator

Sergio Barrachina-Muñoz, Francesc Wilhelmi

Introduction

Introduction to the simulator

- Open source, available at https://github.com/wn-upf/Komondor
- Based on COST
  - Implementation of IEEE 802.11ax novel functionalities
  - High-density scenarios
  - Ready to handle intelligent agents
- Documentation:
  - User's guide at https://github.com/wn-upf/Komondor/blob/master/Documentation/User%20guide/LaTeX%20files/komondor_user_guide.pdf
  - Technical tutorial at https://github.com/wn-upf/Komondor/blob/master/Documentation/Tutorial/LaTeX%20files/komondor_tutorial.pdf

COST

- CompC++ library that allows generating discrete event simulations
- Main website: http://www.ita.cs.rpi.edu/cost.html

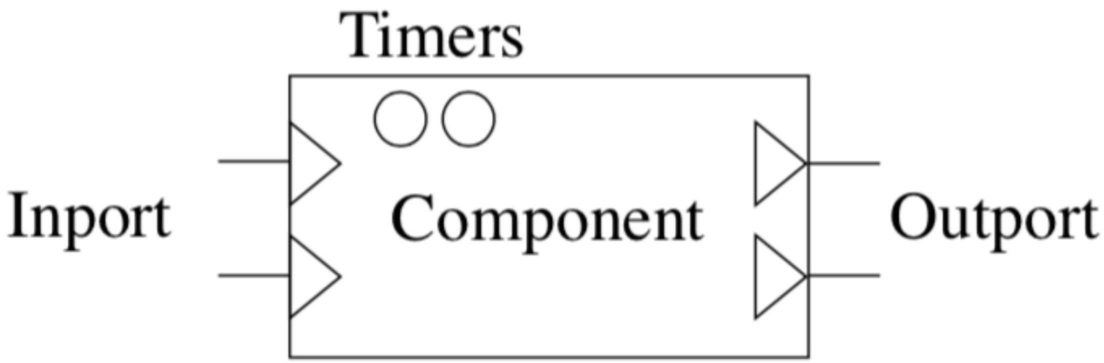


Fig. 1: Component in COST

- Nodes are represented by components
- Message exchange between nodes through *outport/inport* connections
- Timers for triggering events (e.g., end of transmission)

Overview

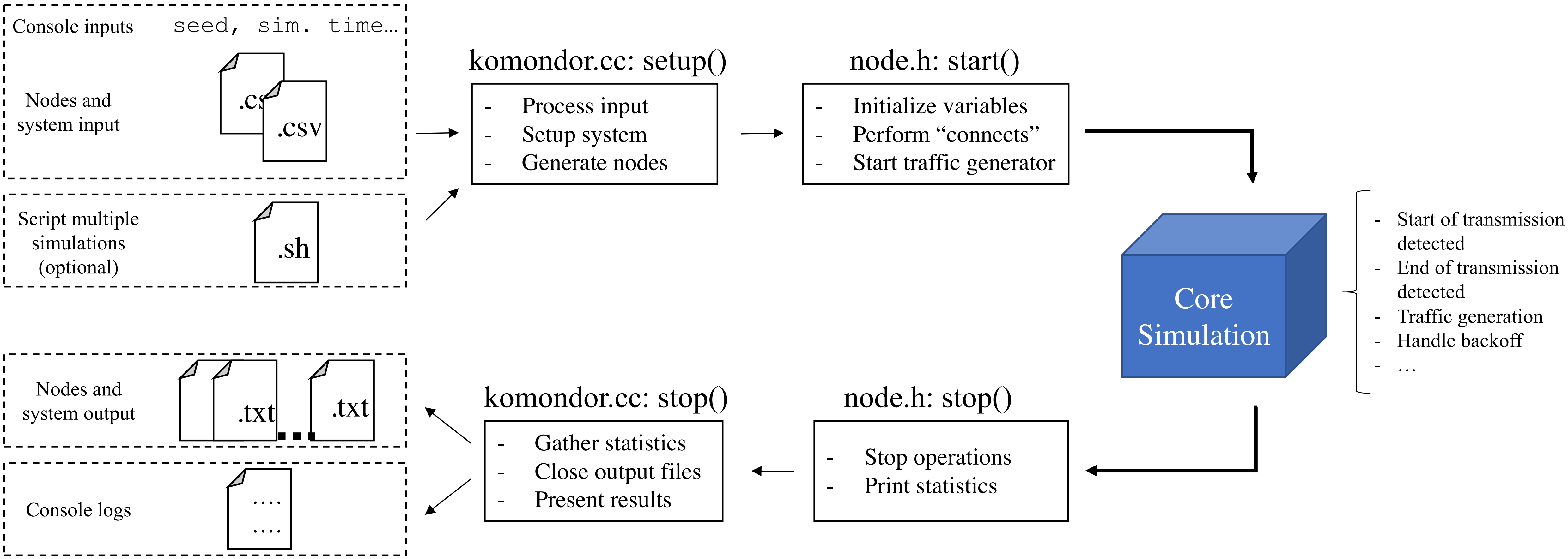


Fig. 2: Komondor flowchart

IEEE 802.11 Features

Channel Access

- Distributed Coordination Function (DCF): Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) with Binary Exponential Backoff (BEB)
  - Slotted vs Continuous Backoff (BO)
  - Uniform vs Exponential distributions for BO calculation
- Capture Effect (CE): stronger-first approach

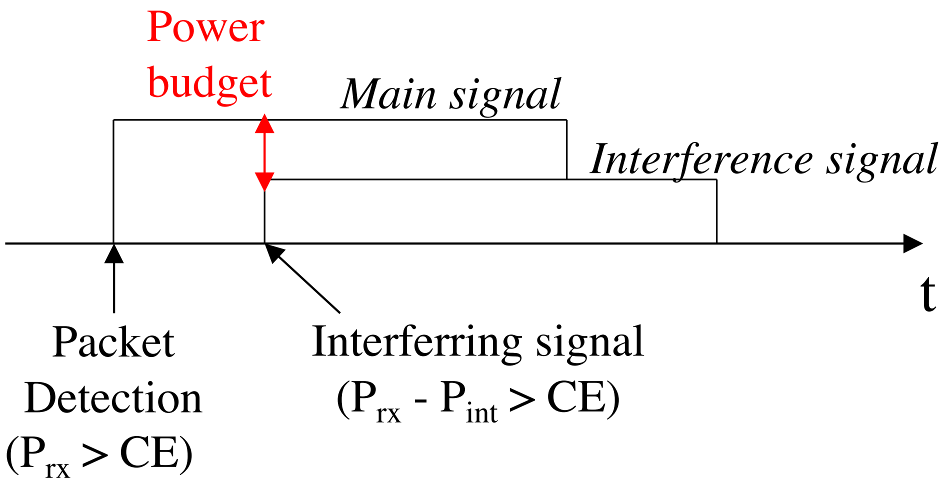


Fig. 3: Capture Effect approach

RTS/CTS

- Ready-To-Send/Clear-To-Send (RTS/CTS) is mandatory
- Virtual carrier sensing is done

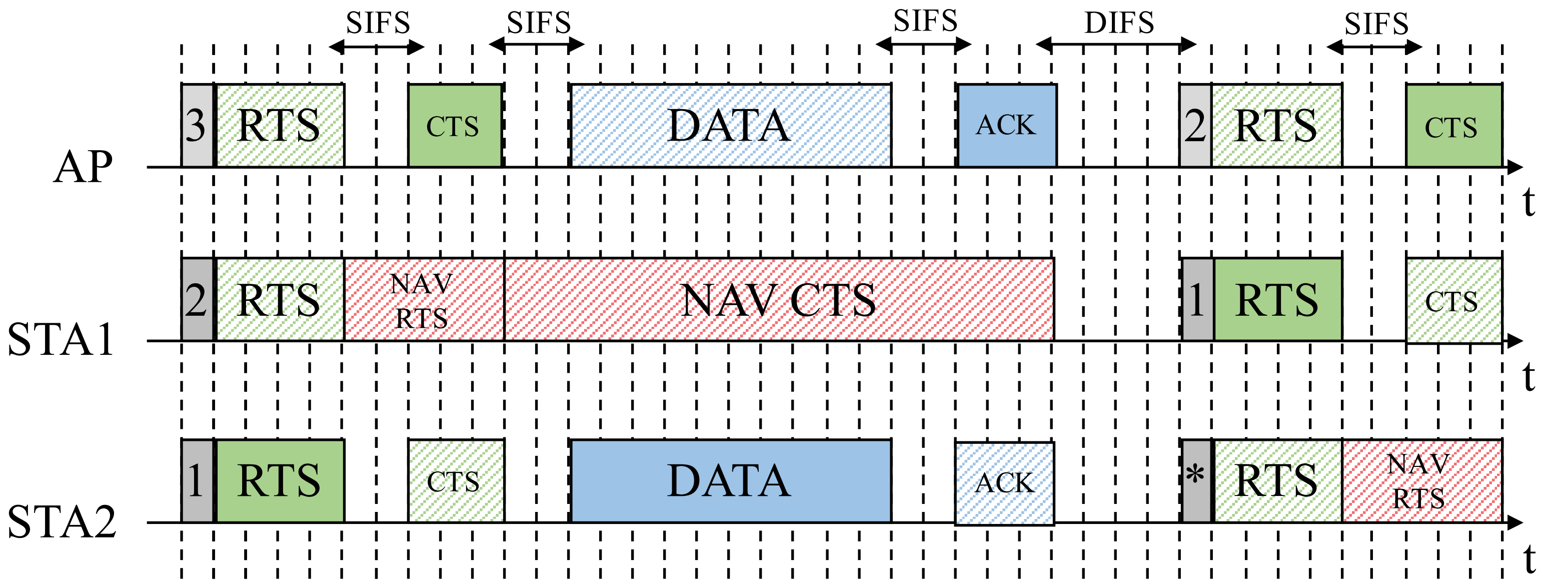


Fig. 4: RTS/CTS utilization example

Channel Bonding

Several implemented policies:

- Only Primary (OP)
- Static Channel Bonding (SCB):
- Always-max (AM)
- Probabilistic uniform (PU)

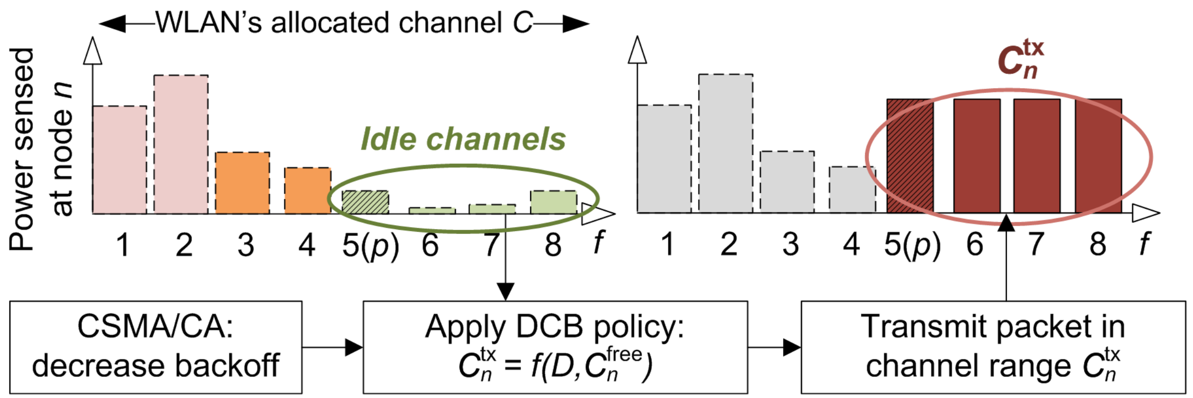


Fig. 5: Channel access when AM is applied

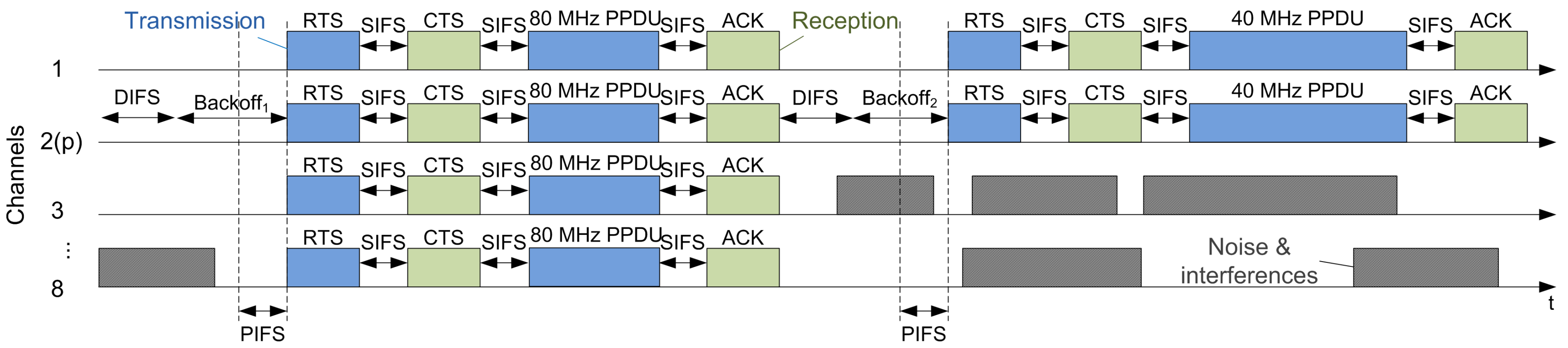


Fig. 6: CSMA/CA temporal evolution under the utilization of AM

Packet Aggregation

- Concatenation of N MPDUs to be sent over the same packet transmission
- Acknowledged by a Block-ACK (BACK)

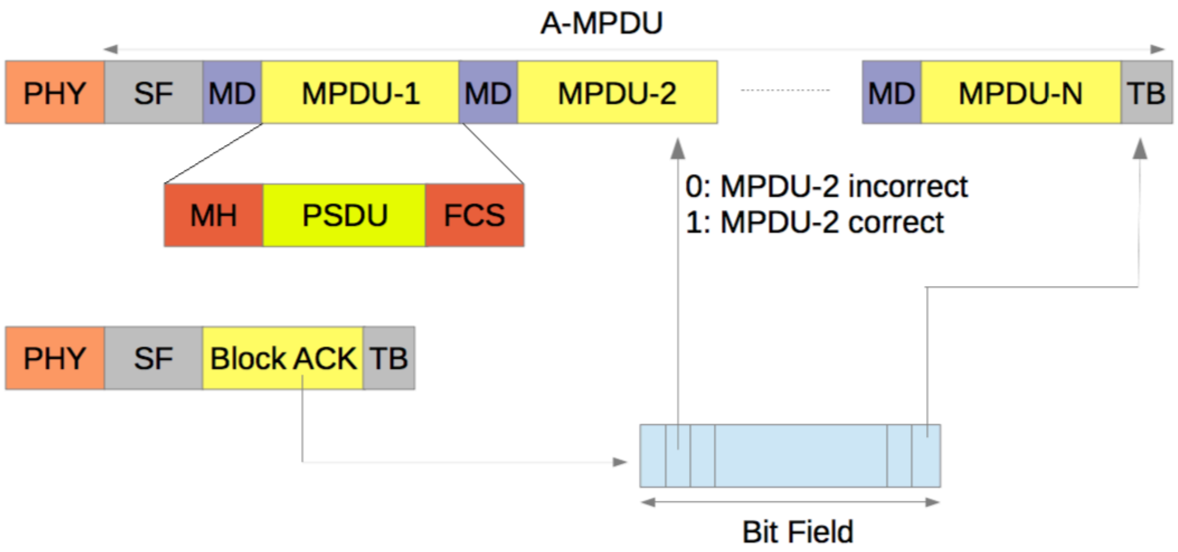


Fig. 7: Packet aggregation for a single transmission

Design Principles

Architecture based on states

- The IEEE 802.11ax-based Simulator considers several states to capture the behavior of nodes
  - Sensing
  - NAV
  - Transmitting an RTS or a CTS
  - Receiving an RTS or a CTS
  - Transmitting DATA
  - Receiving DATA
  - …

Channel Modeling

- Several Path-loss models (easy to add new ones):
  - Free Space Path Loss (FSPL)
  - Okumura-Hata model
  - Generic indoor model
  - IEEE 802.11ax residential scenario model
- Different adjacent channel interference models:
  - No interference
  - Limited interference: only adjacent channels leak power
  - Total interference: all the channels leak power (20 dB per channel)

Assumption: the incoming power in a given receiver is assumed to be the same during the entire transmission

Traffic Modeling

Three implemented models for traffic generation:

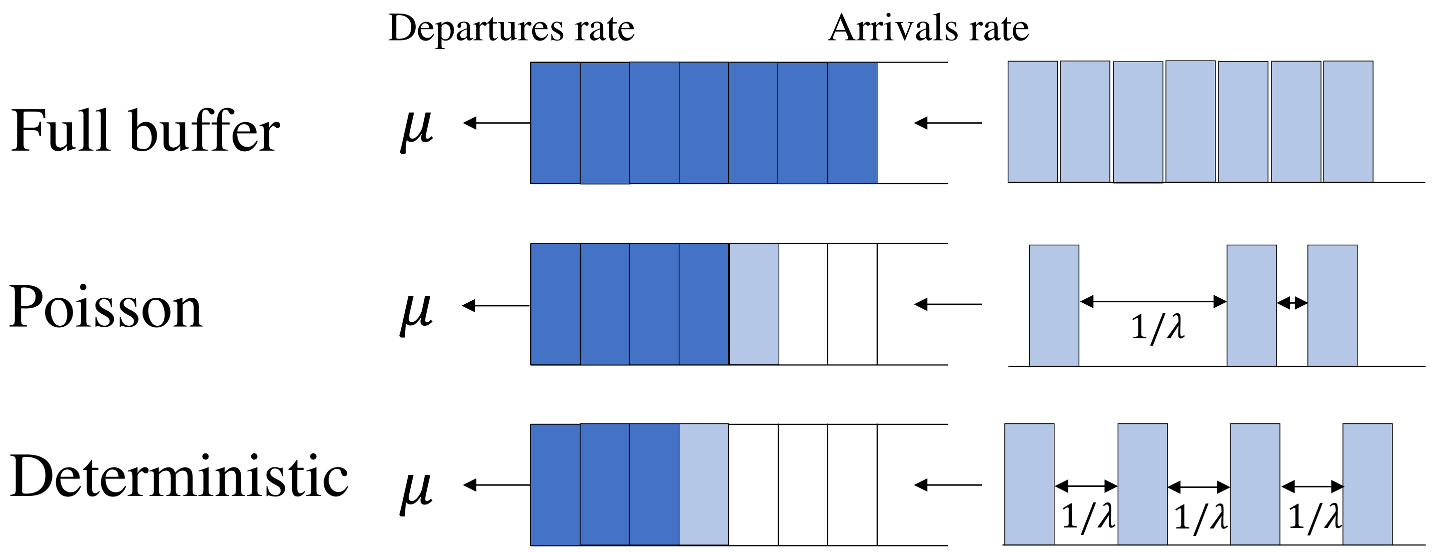


Fig. 8: Traffic generation models

Link Modeling

- IEEE 802.11ax MCS are used

MCS index	SINR interval (dBm)	Modulation type	Coding rate	Data rate (Mbps)			
				20 MHz	40 MHz	80 MHz	160 MHz
0	[-82, -79)	BPSK	1/2	4	8	17	34
1	[-79, -77)	QPSK	1/2	16	33	68	136
2	[-77, -74)	QPSK	3/4	24	49	102	204
3	[-74, -70)	16-QAM	1/2	33	65	136	272
4	[-70, -66)	16-QAM	3/4	49	98	204	408
5	[-66, -65)	64-QAM	2/3	65	130	272	544
6	[-65, -64)	64-QAM	3/4	73	146	306	613
7	[-64, -59)	64-QAM	5/6	81	163	340	681
8	[-59, -57)	256-QAM	3/4	98	195	408	817
9	[-57, -54)	256-QAM	5/6	108	217	453	907
10	[-54, -52)	1024-QAM	3/4	122	244	510	1021
11	≥ 52	1024-QAM	5/6	135	271	567	1143

Table 1: IEEE 802.11ax MCS table

Assumption: The MCS is computed at the beginning of the simulation, based on the power received from the transmitter

Collisions Modeling

- Packet losses occur if:
  - The destination is already transmitting
  - The signal strength is not strong enough ($P_{rx} < CCA$)
  - The CE is not accomplished due to interference
  - The destination is already receiving a packet and the CE condition is still accomplished for the first transmission
  - The destination is in NAV
  - Backoff collisions

Validation

System parameters

- IEEE 802.11ax parameters are considered
  - Channel access
  - Frames length
  - Channelization
  - …

Parameter	Description	Value
CW_{min}	Min. contention window	16
m	Backoff stage	5
CCA	CCA threshold	-82 dBm
P_{tx}	Transmission power	15 dBm
G_{tx}	Transmitting gain	0 dB
G_{rx}	Reception gain	0 dB
L_{data}	Length of a data packet	12000 bits
L_{BACK}	Length of a block ACK	240 bits
L_{RTS}	Length of an RTS packet	160 bits
L_{CTS}	Length of a CTS packet	112 bits
n_{agg}	Num. data packets aggregated	64
CE	Capture effect threshold	20 dB
N	Background noise level	-95 dBm
T_{slot}	Slot duration	9 μs
SIFS	SIFS duration	16 μs
DIFS	DIFS duration	34 μs
PIFS	PIFS duration	25 μs
η	Packet error rate	0.1
f_c	Central frequency	5 GHz
T_{ofdm}	OFDM symbol duration	16 μs
T_{phy}	Legacy PHY header duration	20 μs
n_{ss}	SU spatial streams	1
T_{phy}^{HE}	HE header duration	32 μs
L_{sfF}	Length of MAC's service field	16 bits
L_{del}	Length of MAC's MPDU delimiter	32 bits
L_{mac}	Length of MAC header	272 bits
L_{tail}	Length of MAC's tail	6 bits

Tbl. 2: IEEE 802.11ax PHY & MAC parameters

Basic Operation

Scenario

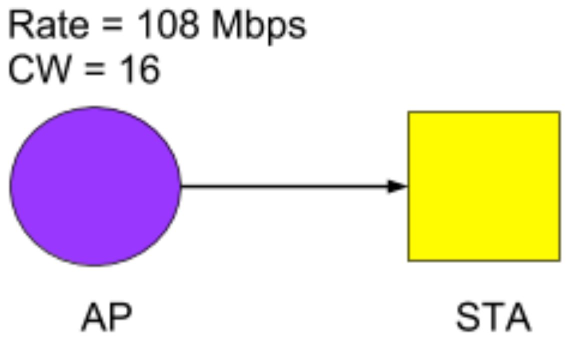


Fig. 9: Scenario 1

	Position AP (m)	Position STA (m)	Channel	Transmit power (dBm)	CCA (dBm)
AP	[2,2,0]	-	1	20	-68
STA A	-	[0,0,0]	1	20	-68

Tbl. 3: Configuration Scenario 1

Results

Packet aggregation (N = 64)		
Komondor	ns3	Bianchi
91.45 Mbps	90.71 Mbps	91.44 Mbps
Single packet (N = 1)		
Komondor	ns3	Bianchi
26.87 Mbps	25.28 Mbps	26.87 Mbps

Tbl. 4: Results Scenario 1

Two STAs

Scenario

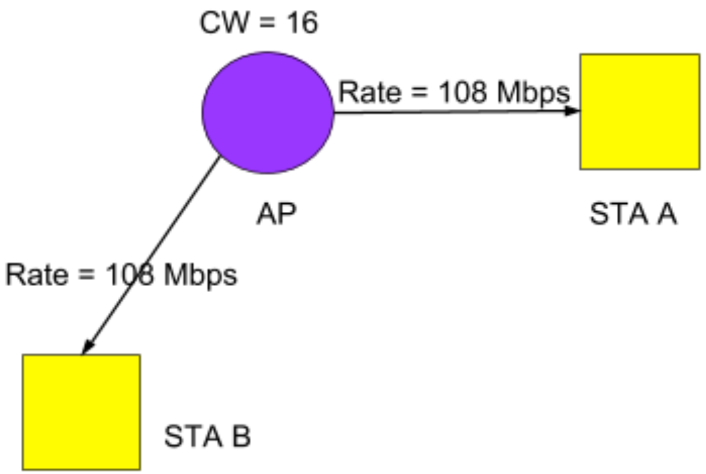


Fig. 9: Scenario 2

	Position AP (m)	Position STA (m)	Channel	Transmit power (dBm)	CCA (dBm)
AP	[2,2,0]	-	1	20	-68
STA A	-	[0,0,0]	1	20	-68
STA B	-	[4,4,0]	1	20	-68

Tbl. 5: Configuration Scenario 2

Results

Packet aggregation (N = 64)		
Komondor	ns3	Bianchi
91.45 Mbps	90.71 Mbps	91.44 Mbps
Single packet (N = 1)		
Komondor	ns3	Bianchi
26.87 Mbps	25.28 Mbps	26.87 Mbps

Tbl. 6: Results Scenario 2

Dynamic Channel Bonding

Scenarios

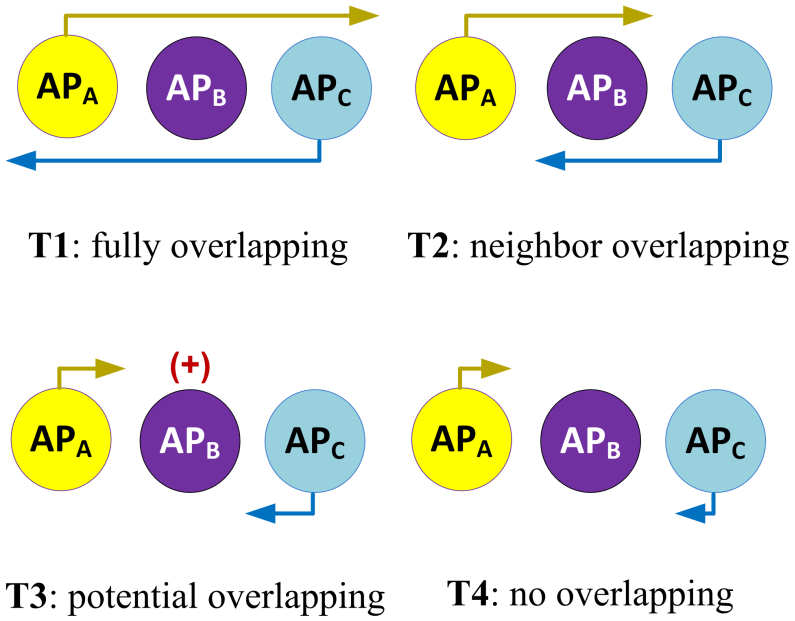


Fig. 10: Scenarios for DCB validation

Results

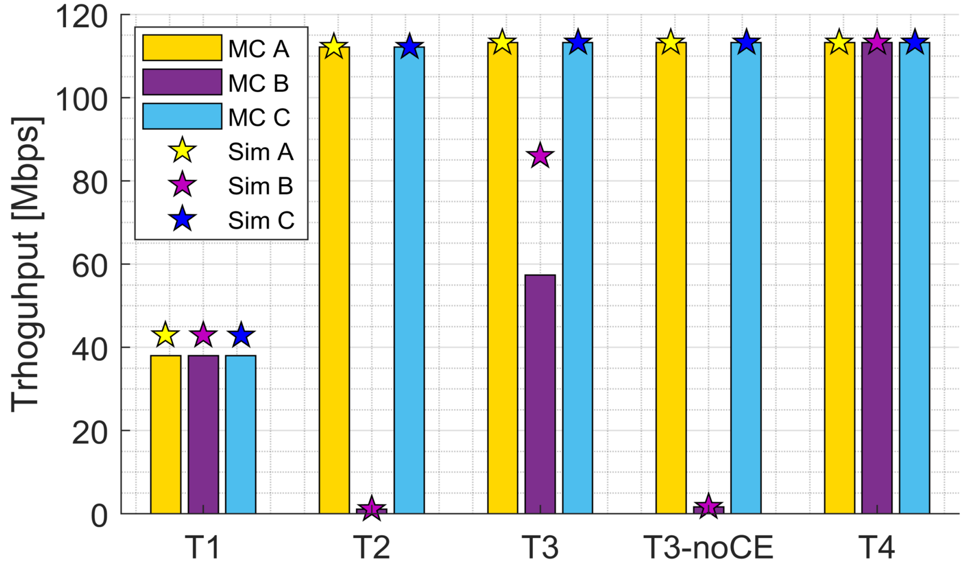


Fig. 11: Results DCB validation

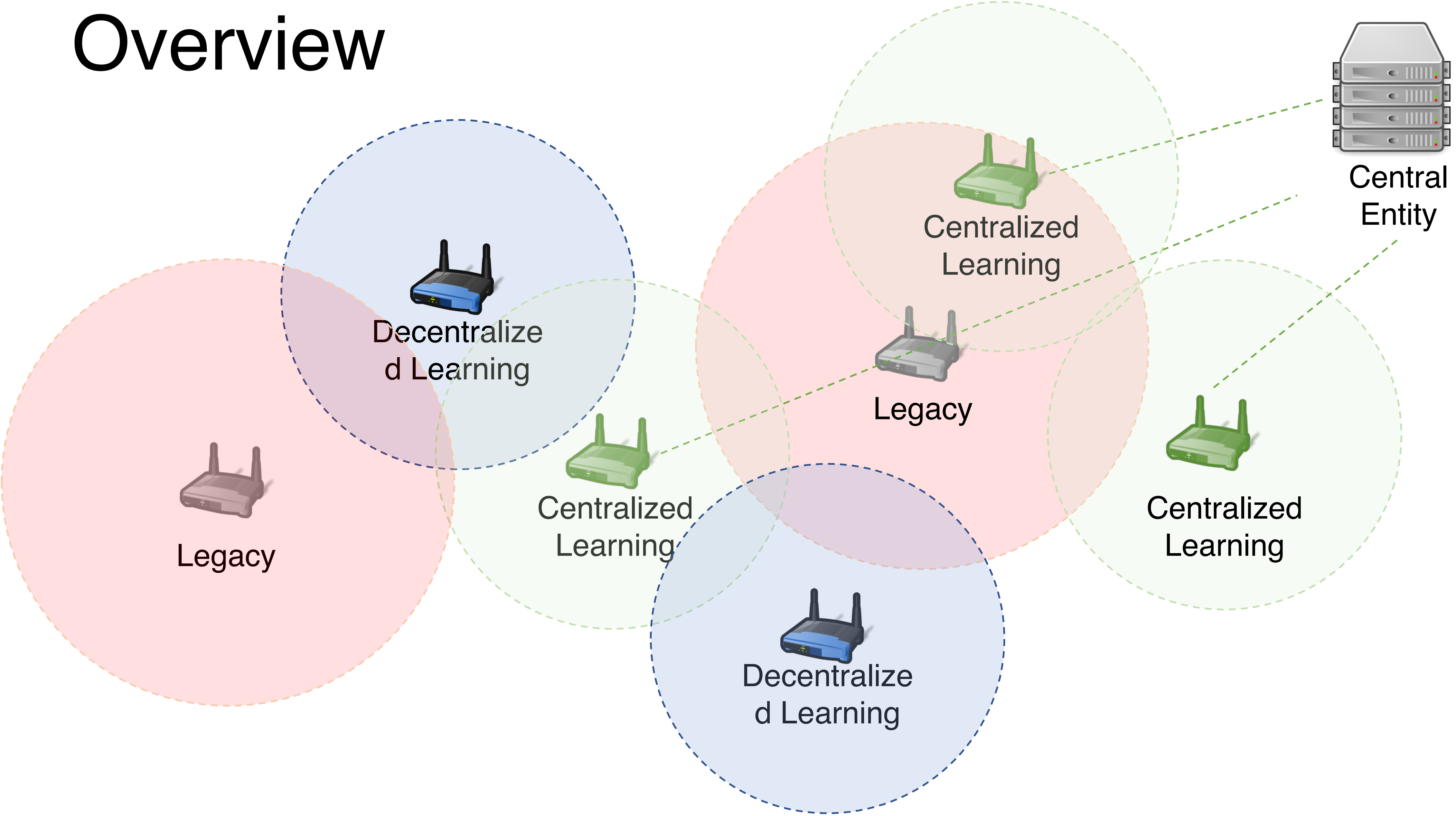
More information in Barrachina-Munoz, S., Wilhelmi, F., & Bellalta, B. (2018). [Performance Analysis of Dynamic Channel Bonding in Spatially Distributed High Density WLANs](). *arXiv preprint arXiv:1801.00594*.

Intelligent Agents

Some remarks

- Agents are introduced to modify the configuration of simulated WLANs in order to maximize a certain performance metric (local or globally)
- Each agent is associated to an AP, so that all the information is shared between these two type of entities (we assume that the agent is located in the AP)
- Communication between agents is not implemented yet, but future developments contemplate centralized approaches
  - Agents share information with a central entity, which takes decisions
  - Adaptive delay for such a communication

Overview



Central
Entity
Centralized
Learning
Decentralize
d Learning
Legacy
Centralized
Learning
Legacy
Centralized
Learning
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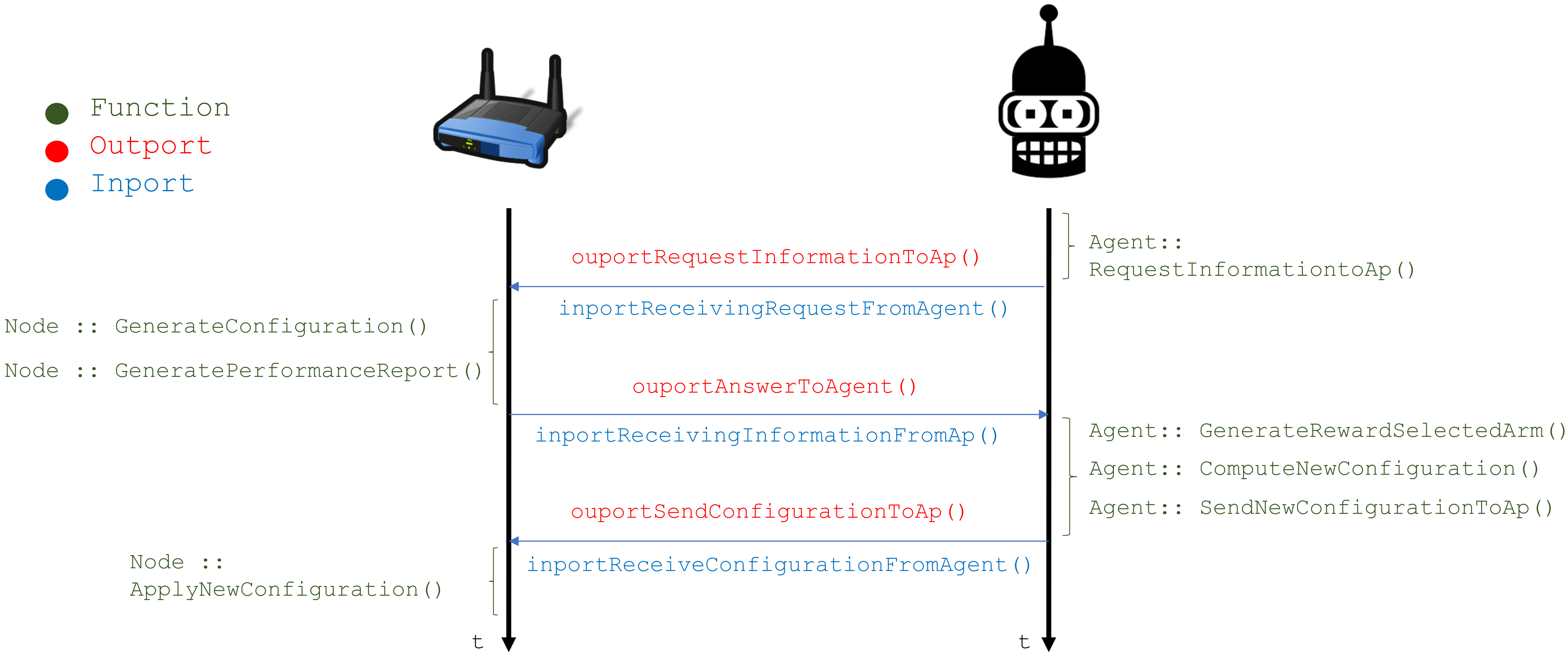
AP-Agent communication



Agent-oriented functionalities at the AP

1. Wait for agent requests → `inportReceivingRequestFromAgent()` `ouportRequestInformationToAp()`
2. Encapsulate important information regarding the current configuration (transmit power, CCA, MCS…) and the offered performance (packets sent, packets lost, collisions by hidden node…) → `GenerateConfiguration()` `GeneratePerformanceReport()`
3. Send information to the Agent → `ouportAnswerToAgent()`
4. Wait for the new configuration granted by the Agent → `inportReceiveConfigurationFromAgent()`
5. Apply changes and broadcast new configuration to STAs → `ApplyNewConfiguration()`

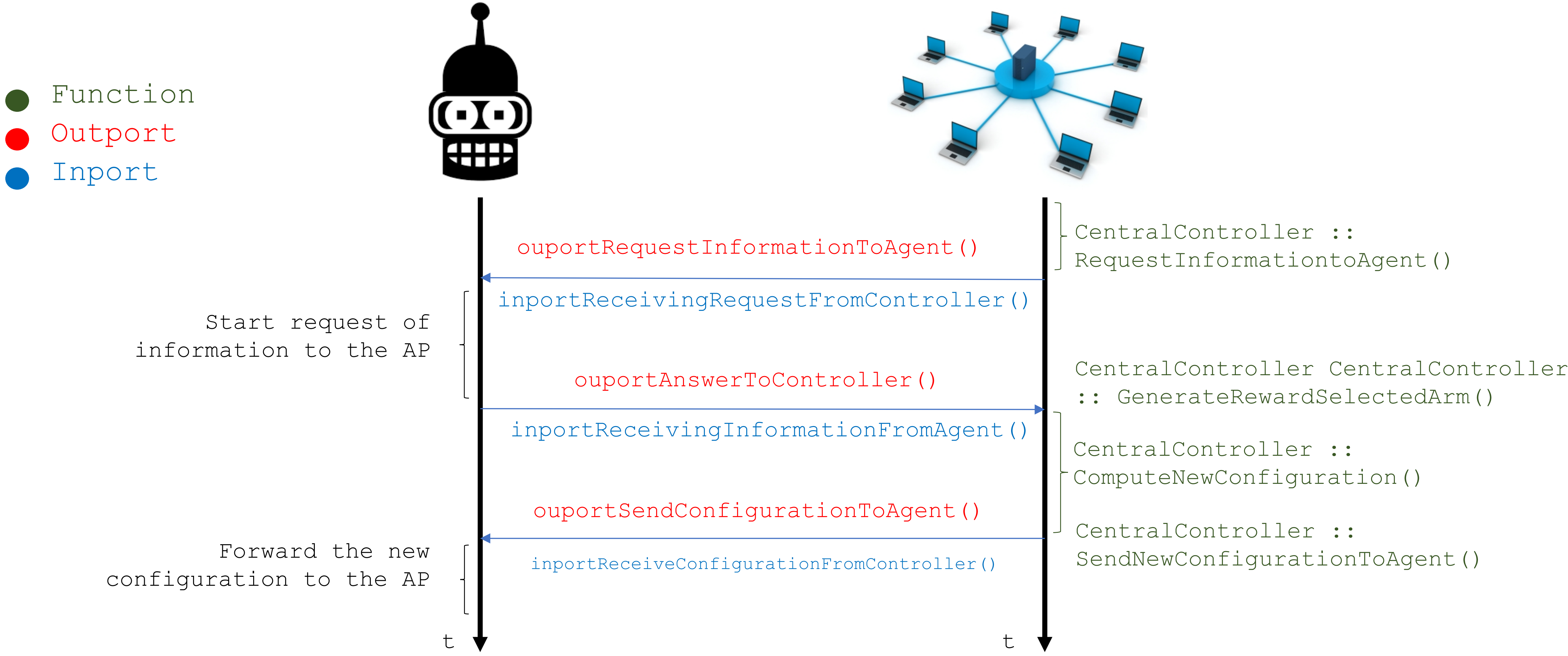
Agent functionalities

1. Generate and send requests for APs periodically → `RequestInformationtoAp()` `ouportRequestInformationToAp()`
2. Wait for the requested information → `inportReceivingInformationFromAp()`
3. Generate a reward according to the current configuration and performance in the AP → `GenerateRewardSelectedArm()`
4. Draw a new configuration according to updated rewards → `ComputeNewConfiguration()`
5. Send the new configuration to the AP → `SendNewConfigurationToAp()` `ouportSendConfigurationToAp()`

Centralized Learning - Remarks

- In order to perform centralized learning, we have added a central entity that controls the operations done by agents
- The central entity works on the top of the Agent-AP operation
- It is important to remark that agents can be freely assigned to the central entity, so that we can support hybrid scenarios with
  1. Legacy APs
  2. Agent-embedded APs
  3. Centralized agent-embedded APs
- Each agent communicates to the centralized entity in a synchronized manner

Agent-Central Entity (CC) communication



Agent-embedded Architecture