LTEV2Vsim Version 5.4

Developed by CNIT, University of Bologna, and CNR-IEIIT

Event driven dynamic simulator written in MATLAB

Simulates sidelink LTE-V2X and ITS-G5, currently focusing on cooperative awareness

(http://www.wcsg.ieiit.cnr.it/products/LTEV2Vsim.html) https://github.com/alessandrobazzi/LTEV2Vsim

In Version 5.4, compared to Version 5.0:

- Several parameters have been added (e.g., it is now possible to fix the power density in LTE instead of the transmitted power, to change the congestion parameters of ITS-G5, etc.) – Please refer to the «Table of input parameters» and the notes therein
- The outputs have been revised
- The highway and urban scenarios often used in ETSI and 3GPP documents have been added
- The average SINR calculation has been revised (see next slides)
- Packet generation is not anymore necessarily periodic and an optional function calculates automatically the packet generation interval given the vehicle speed following the CAM triggering rules from ETSI
- The LTE allocation process has been improved with the new packet generation (see next slides)
- Revised packet acquisition phase in ITS-G5 (sthe stronger signal within 4us is used)
- CBR and DCC implemented for both technologies following ETSI rules (see next slides)

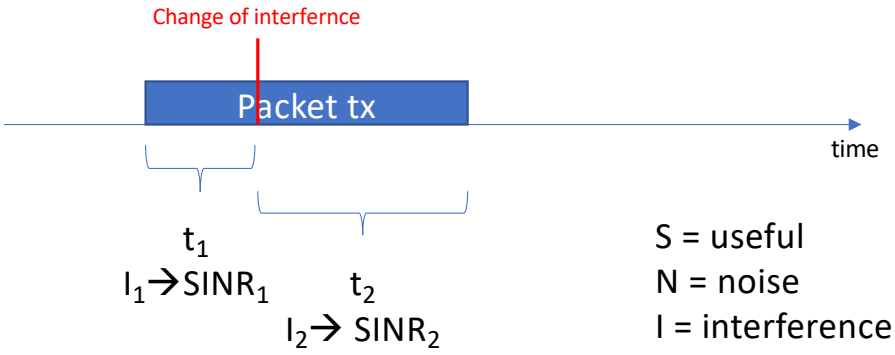
The next slides contain some details on specific aspects
It is suggested to also read the Tutorial of version 3.5b and the comments to version 5.0 before moving to the next slides

MODIFICATIONS IN THE SINR CALCULATION

SINR CALCULATION

Approach before versions 5.4

The SINR was obtained as the average of instantaneous SINR



S = useful
N = noise
I = interference

$$SINR_i = \frac{S}{N + I_i}$$

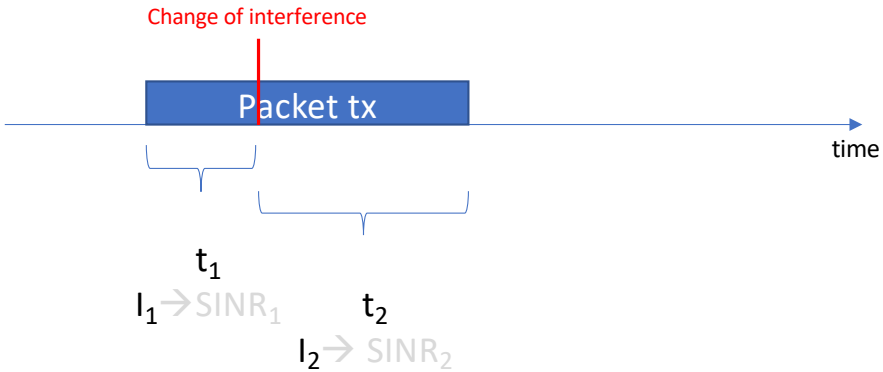
$$SINR_{av} = \frac{\sum(SINR_i \cdot t_i)}{\sum t_i}$$

This way, if we have 2 intervals, t_1=t_2, I_1=0 and I_2→inf we have

$$SINR \approx \frac{S/N + 0}{2} = \frac{1}{2}\frac{S}{N}$$

Approach starting from version 5.4

The SINR is obtained as the ratio between the received power (assumed constant on the short duration of a packet transmission) and the sum of noise power and the average interference, which is teh average of the instantaneous interference



$$I_{av} = \frac{\sum(I_i \cdot t_i)}{\sum t_i}$$

$$SINR_{av} = \frac{S}{N + I_{av}}$$

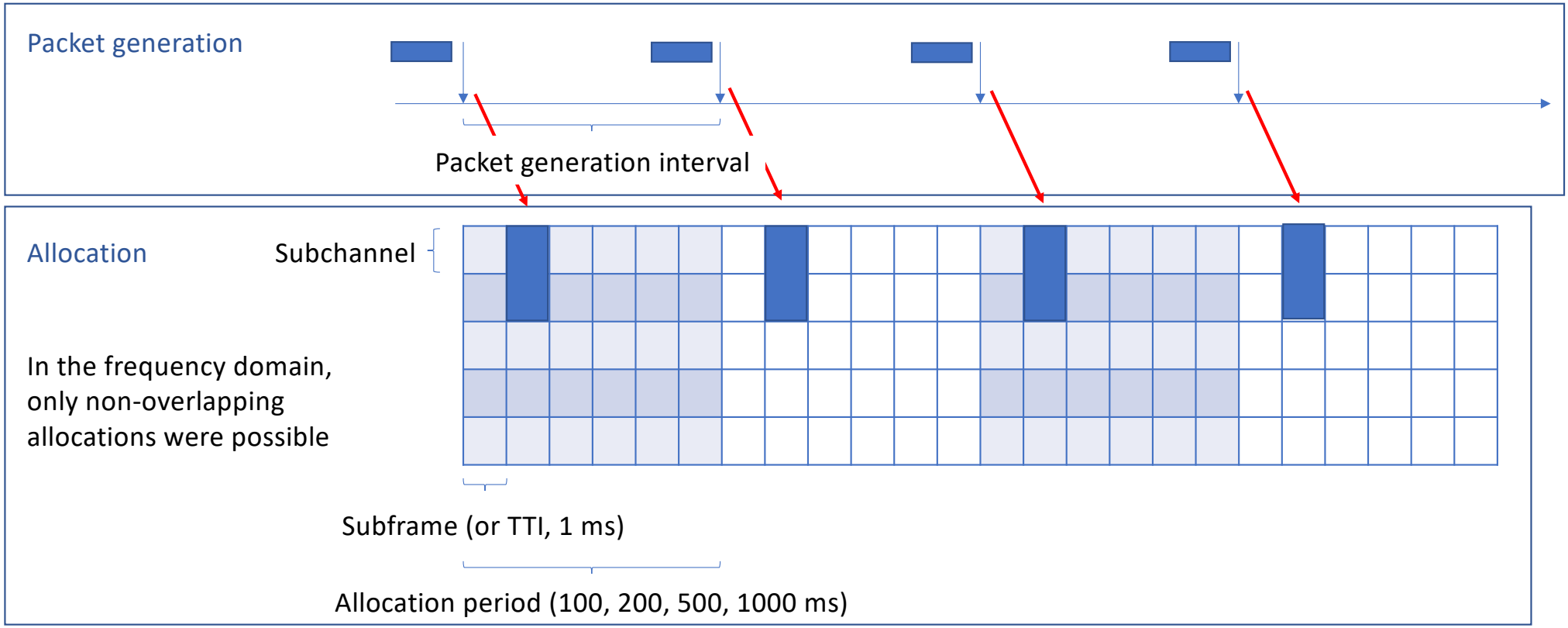
This way, if we have 2 intervals, t_1=t_2, I_1=0 and I_2→inf we have

$$SINR \approx \frac{S}{N + inf/2} \to 0$$

MODIFICATIONS IN THE LTE ALLOCATION PROCESS

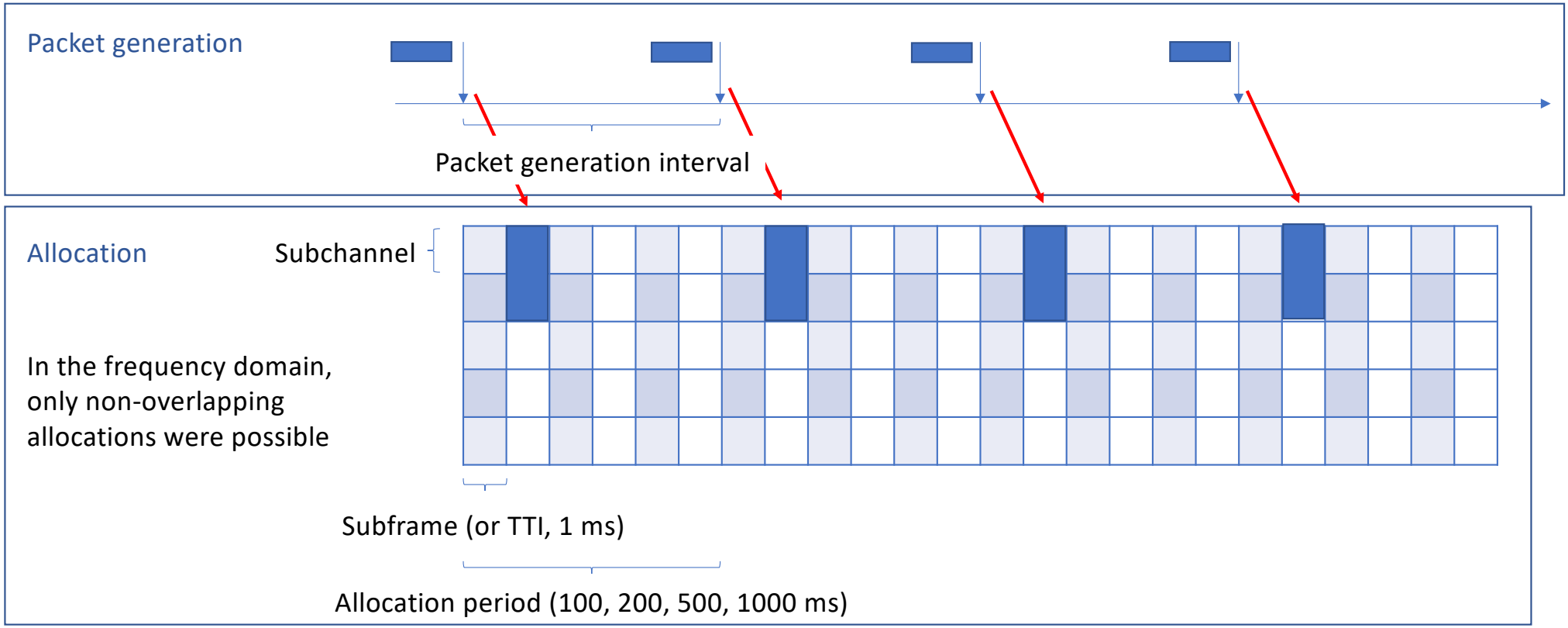
About LTE allocation – Before version 5.0

Time granularity was the allocation period
Overlapping in the frequency domain was not allowed
The packet generation was periodic, with the same period as the allocation periodicity



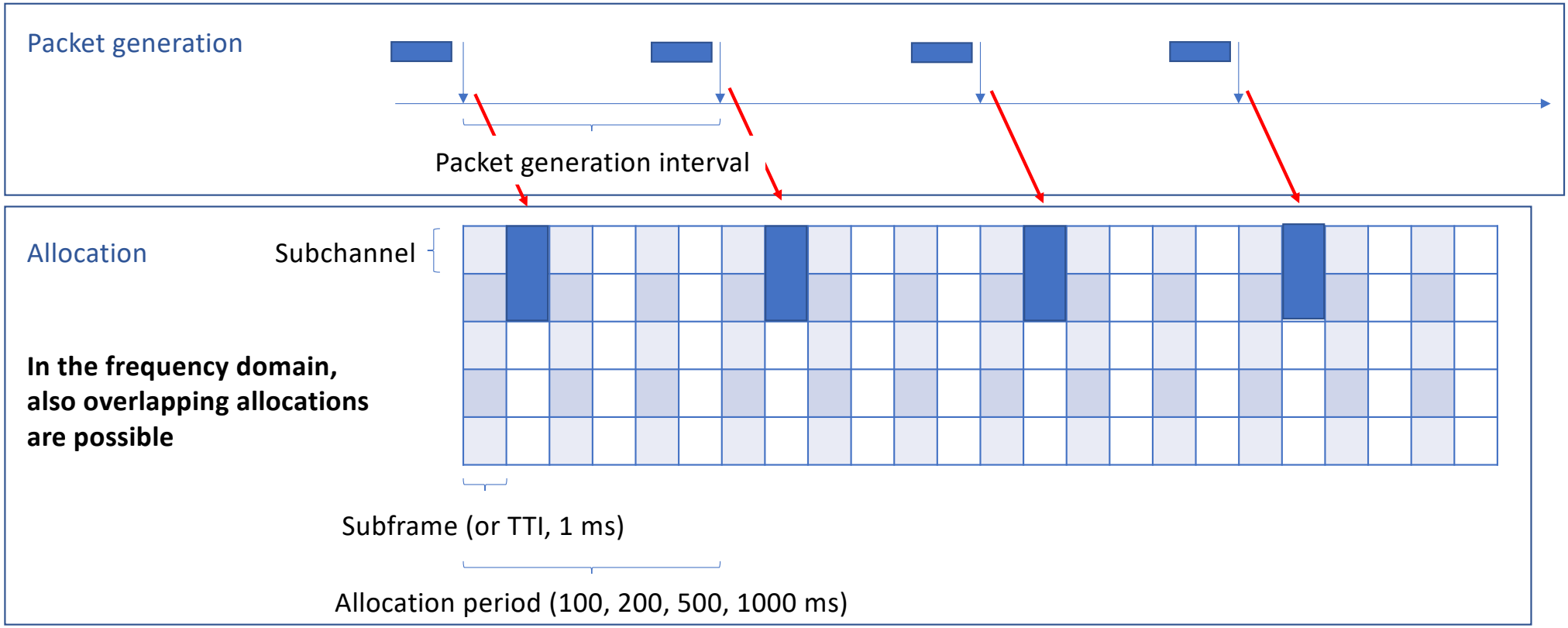
About LTE allocation – From 5.0

Time granularity is now the subframe
Overlapping in the frequency domain was not allowed
The packet generation was periodic, with the same period as the allocation periodicity



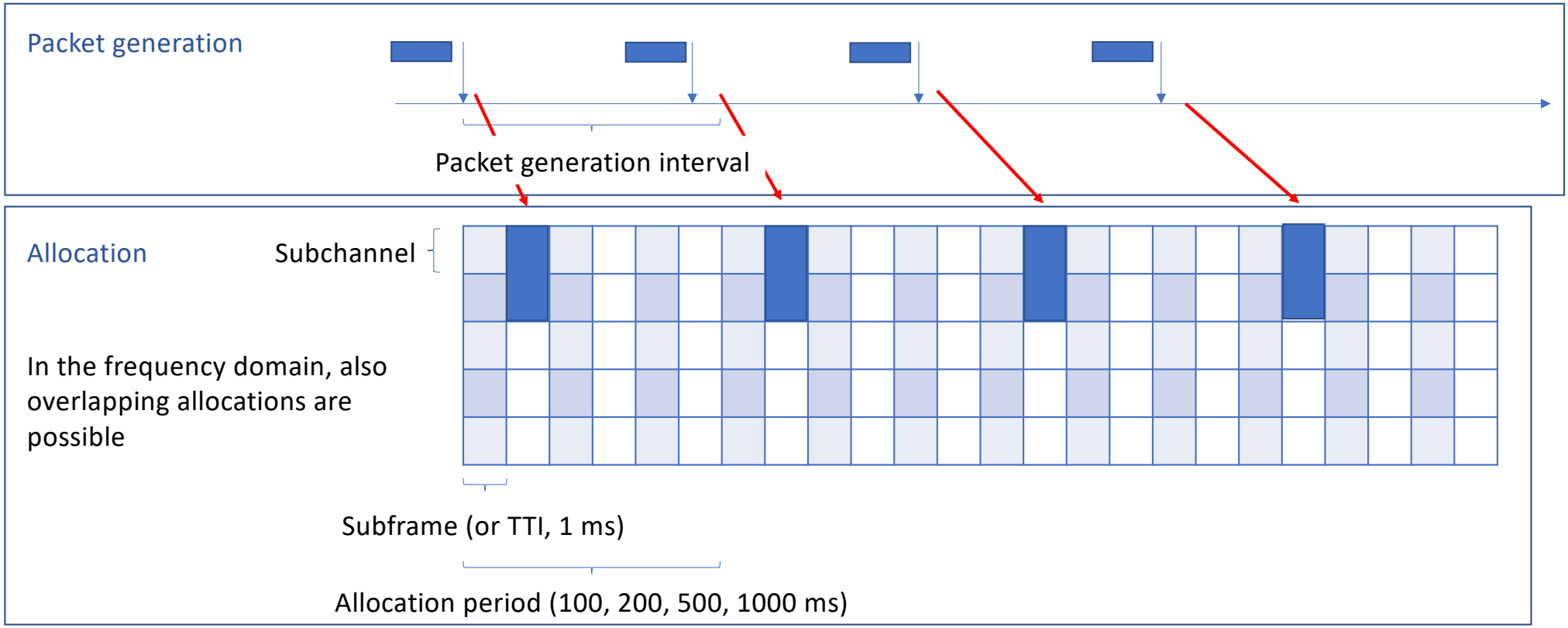
About LTE allocation – First step after v5.0

Overlapping in the frequency domain is allowed
The packet generation was periodic, with the same period as the allocation periodicity



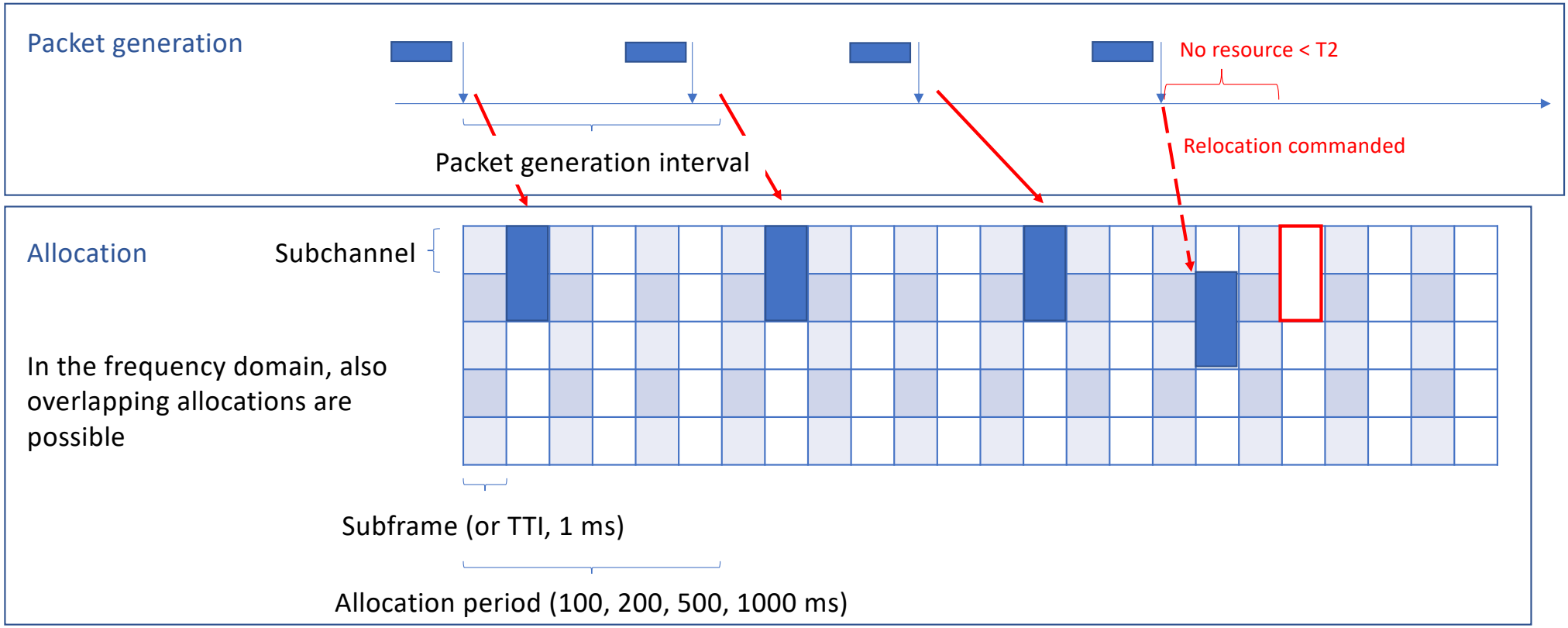
About LTE allocation – Second step after v5.0

The packet generation is periodic, possibly with a different period than the allocation periodicity



About LTE allocation – Third step after v5.0

A relocation is commanded if a resource in not available in the interval set by T1-T2



NOTES ON CHANNEL SENSING AND CBR CALCULATION IN ITS-G5

Channel sensing in ITS-G5/11p

At the instant t_0
A transmission starts (vehicle X)

Per each other vehicle Y:
- if Y is not transmitting or already receiving --- AND
  - if the SINR received from X is above the threshold corresponding to PER=0.9 --- OR
  - If the received power is above -65 dB

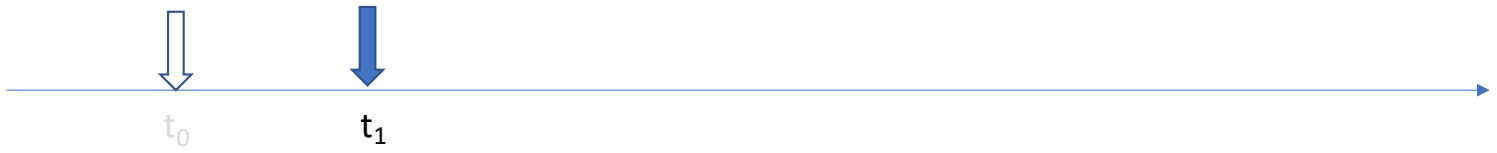
  THEN Y starts receiving from X (might conclude with an error)

NOTE: noise is well below -85 dBm, thus the threshold for assessing the channel as busy when the message is decodable is not used

Channel sensing in ITS-G5/11p

At the instant t_1
A transmission ends (vehicle X)

Per each vehicle Y that was receiving from X or was in wrongly receiving state
- If the received power is below -65 dB
    THEN Y stops receiving
    OTHERWISE moves/remains in wrongly receiving state



NOTE: the node cannot decode a new signal at this time, thus only the -65 dBm threshold is used

Calculation of CBR

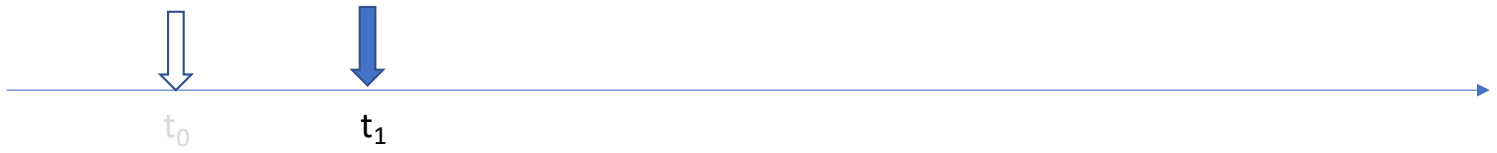
At the instant t_0
A transmission starts (vehicle X)

Per each other vehicle Y:
- if Y is transmitting or the received power is above -85 dB
  THEN Y is in CBR busy state
  OTHERWISE in CBR free state

Calculation of CBR

At the instant t_1
A transmission ends (vehicle X)

Per each other vehicle Y:
- if Y is transmitting or the received power is above -85 dB
  THEN Y is in CBR busy state
  OTHERWISE in CBR free state

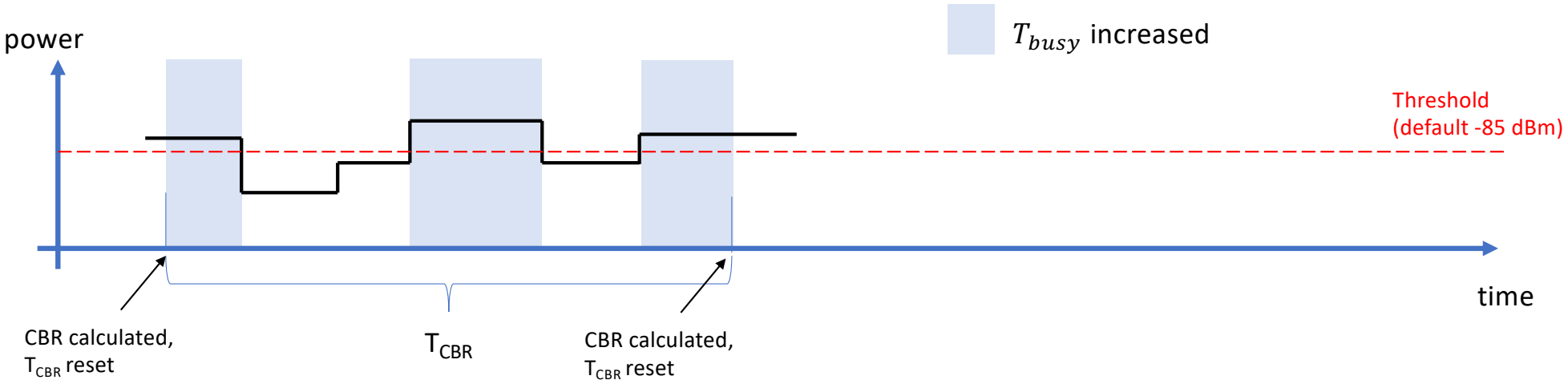


CBR AND DCC CALCULATIONS

ITS-G5: Channel Busy Ratio (CBR)

REF: ETSI EN 302 663

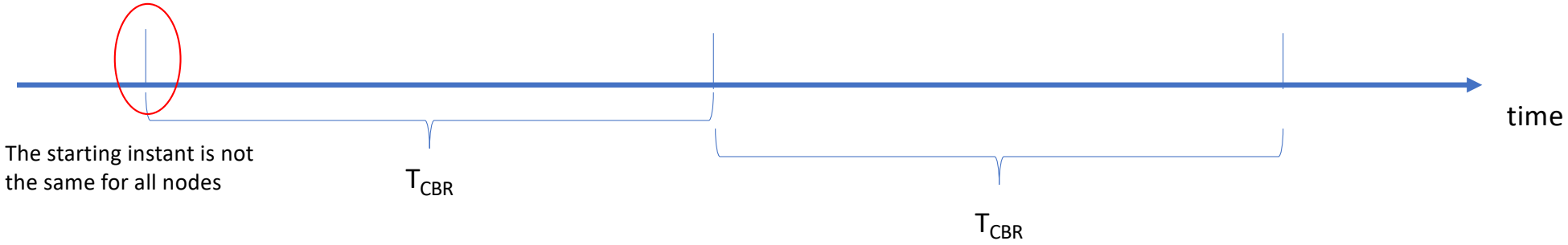
- The occupancy of the channel T_{busy} is updated per each vehicle at each transmission start or end; the calculation of T_{busy} is based on the evaluation:
  sensed busy if $\sum P_{r_i} > S_{busy}$, not busy otherwise
  where $\sum P_{r_i}$ is the overall received power and S_{busy} is a threshold named phyParams.PrxSensWhenSynch, by default set to -85 dBm;
- The CBR is then calculated every T_{CBR} =100 ms as
  $CBR = T_{busy} / T_{CBR}$
  (T_{busy} is reset everytime a new CBR is calculated)



ITS-G5: Channel Busy Ratio (CBR)

REF: ETSI EN 302 663

- In order to avoid synchronization among nodes and preserve simulation speed, each vehicle performs the CBR calculation every T_{CBR}, starting from a different instant randomly selected within one of T_{CBR}/N instants, where N is a parameter called simParams.cbrSensingIntervalDesynchN and set by default to 100



ITS-G5: DCC

REF: ETSI EN 302 663

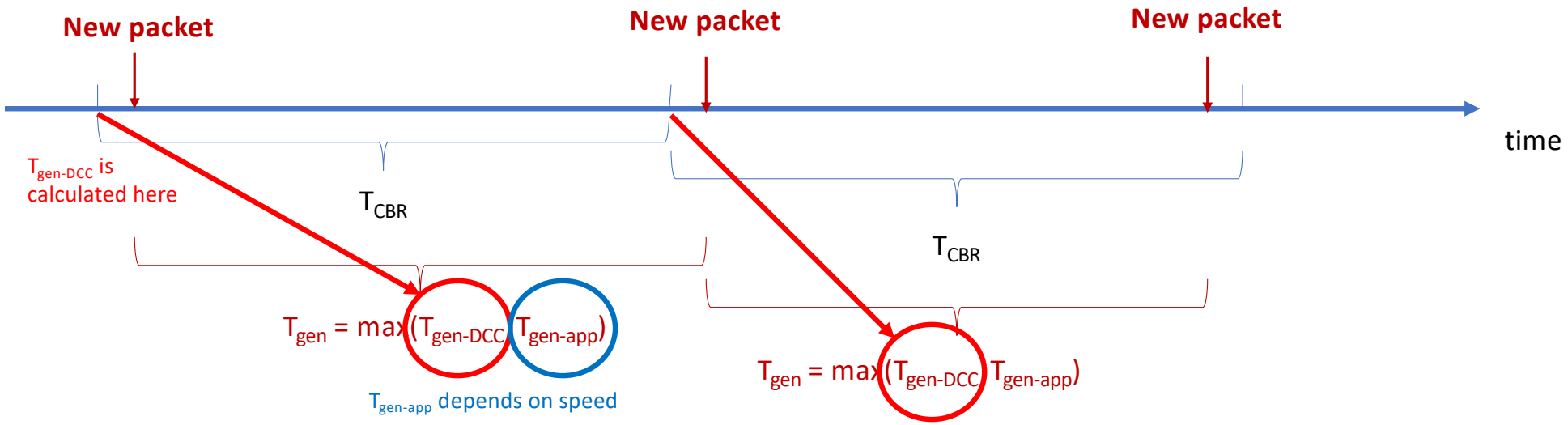
- Based on CBR, the minimum generation interval is calculated as

$$T_{gen-DCC} = \min(1, t_{pack}[ms] \cdot 4 \cdot \frac{CBR-0.62}{CBR}) \text{ [seconds]}$$

(note: there is no need to check CBR>0.62)

- Once a new packet is generated, the next one is planned based on

$$T_{gen} = \max(T_{gen-DCC}, T_{gen-app}) \text{ [seconds]}$$

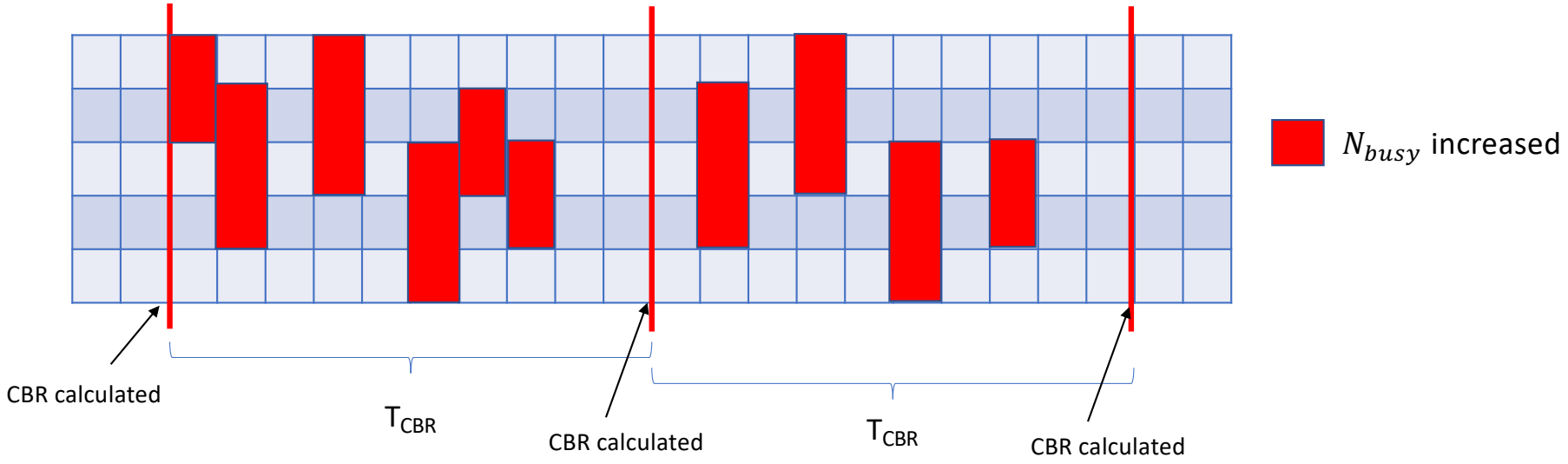


LTE-V2X: Channel Busy Ratio (CBR)

REF: ETSI TS 103 574
ETSI TS 136 214

- The occupancy of one subchannel is measured based on the evaluation:
  sensed busy if $P_{r_s} > S_{busy}$, not busy otherwise
  where P_{r_s} is the power received in suchannel s and S_{busy} is a threshold fixed to -94 dBm;

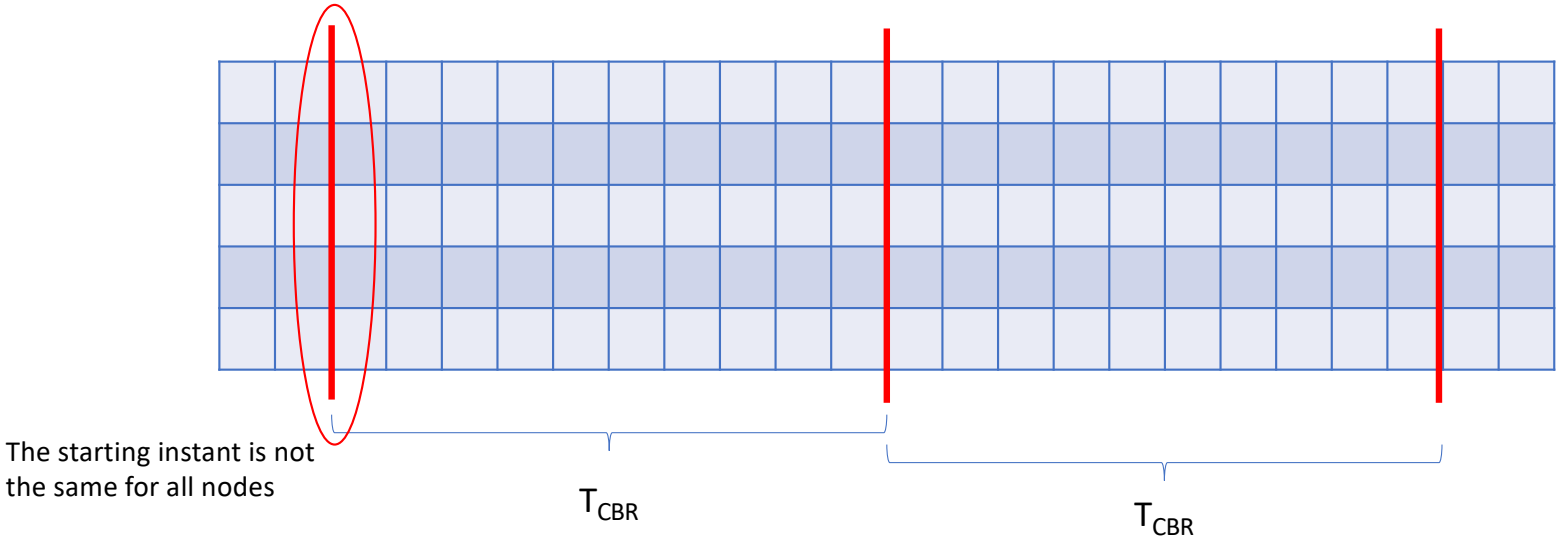
- The CBR is then calculated every T_{CBR} =100 ms as
  $CBR = N_{busy} / N_{CBR}$
  where N_{busy} is the number of suchannels sensed as busy in T_{CBR} and N_{CBR} is the overall number of suchannels in T_{CBR}



LTE-V2X: Channel Busy Ratio (CBR)

REF: ETSI TS 103 574
ETSI TS 136 214

- In order to avoid synchronization among nodes and preserve simulation speed, each vehicle performs the CBR calculation every T_{CBR}, starting from a different instant randomly selected within one of T_{CBR}/N instants, where N is a parameter called simParams.cbrSensingIntervalDesynchN and set by default to 100



LTE-V2X: DCC

REF: ETSI TS 103 574
ETSI TS 136 214

- Based on CBR, the variable CR_{limit} is calculated as (PPPP=5 for CAMs is assumed)

  $CR_{limit-PPPP5} = 1$ if CBR<=0.3,
  $CR_{limit-PPPP5} = 0.03$ if 0.3<CBR<=0.65,
  $CR_{limit-PPPP5} = 0.006$ if 0.65<CBR<=0.8,
  $CR_{limit-PPPP5} = 0.003$ if CBR>0.8

  and the minimum generation interval is derived as

  $$T_{gen-DCC} = \frac{n_{subch-packet}}{n_{subch}} \frac{T_{subframe}}{CR_{limit}}$$

- Once a new packet is generated, the next one is planned based on

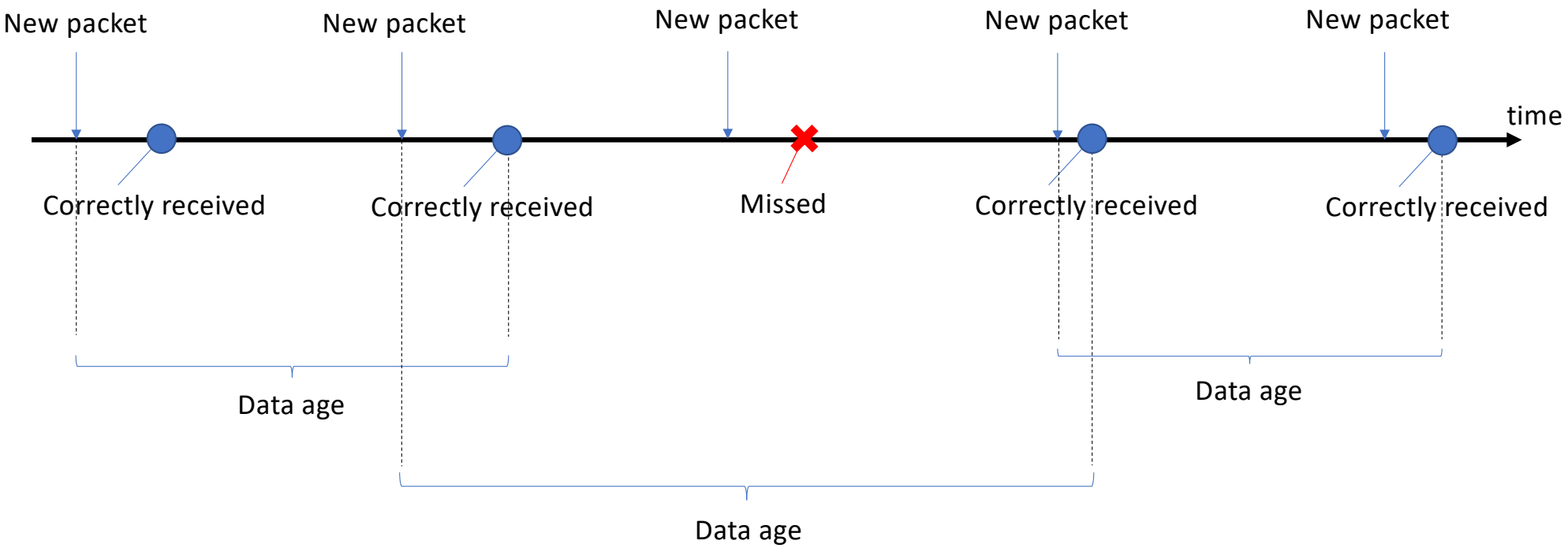
  $T_{gen} = \max(T_{gen-DCC}, T_{gen-app})$ [seconds]

  (same as in ITS-G5)

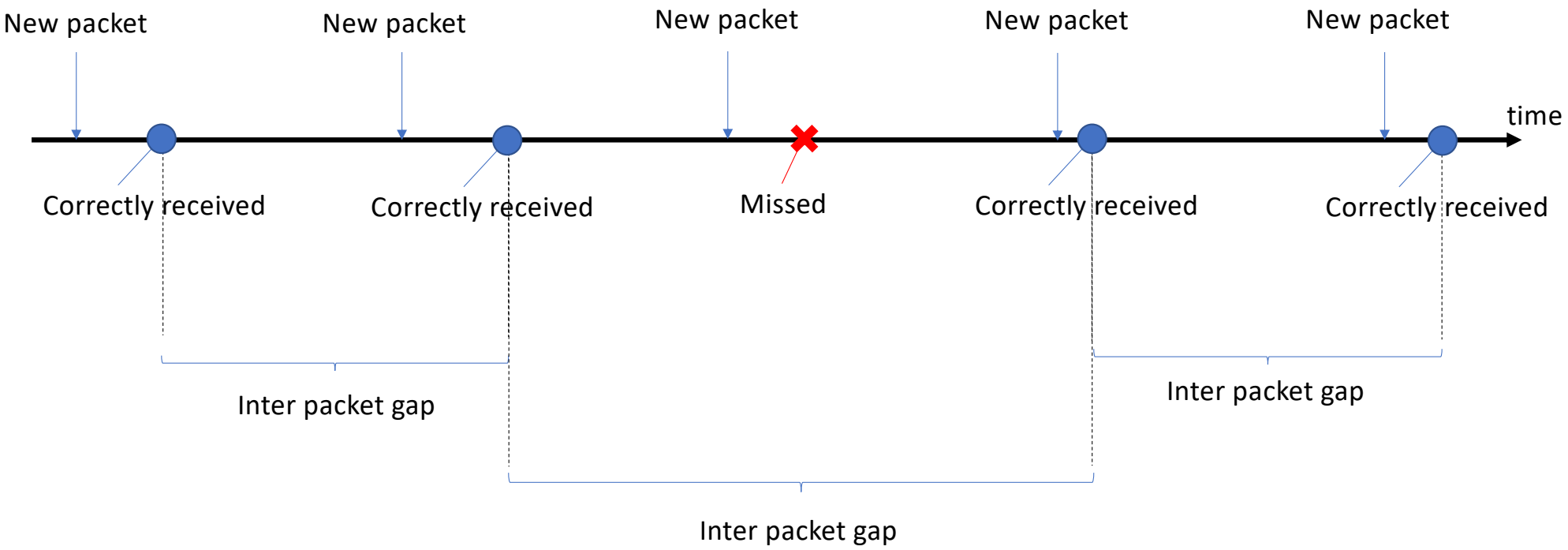
- Note: it is assumed that the resources allocated at the access layer are at a constant periodicity, which is not in general synchronized with the generation interval

DEFINITIONS OF DATA AGE, INTER-PACKET GAP, END-TO-END DELAY

DATA AGE


New packet
New packet
New packet
New packet
New packet
time
Correctly received
Correctly received
Missed
Correctly received
Correctly received
Data age
Data age
Data age

INTER PACKET GAP



END-TO-END DELAY