

## Extensions of CAM and DENM for UC2 – Plausibility Checks and Metadata Evaluation

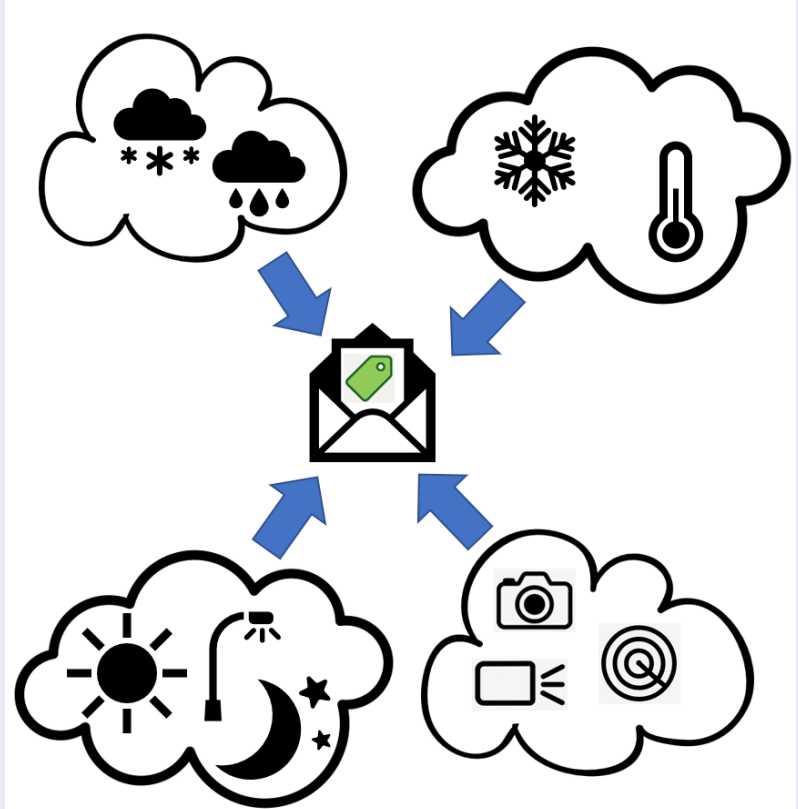
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### General approach

- In UC2, the approach is to judge the sender/information just by information received from this particular sender (CAMs, DENMs)
- By checking (redundant) information on plausibility, it is possible to achieve a trustworthiness of the sender
- By assessing given metadata, trustworthiness in / usability of the data sent can be determined
- With these two ratings given, a trust-value between 0 and 1 will be calculated, to decide, whether the planned functionality (braking) can be executed, or if some degradation-mechanisms (slowly slowing down, warning to the driver (< L5)) will apply
- To provide reliable results, it will be necessary to extend the messages used (CAMs, DENMs) to a certain extend

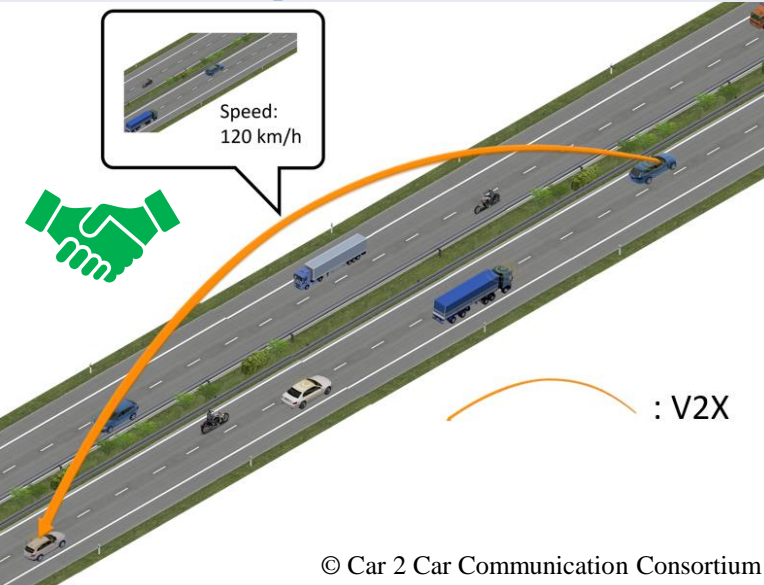
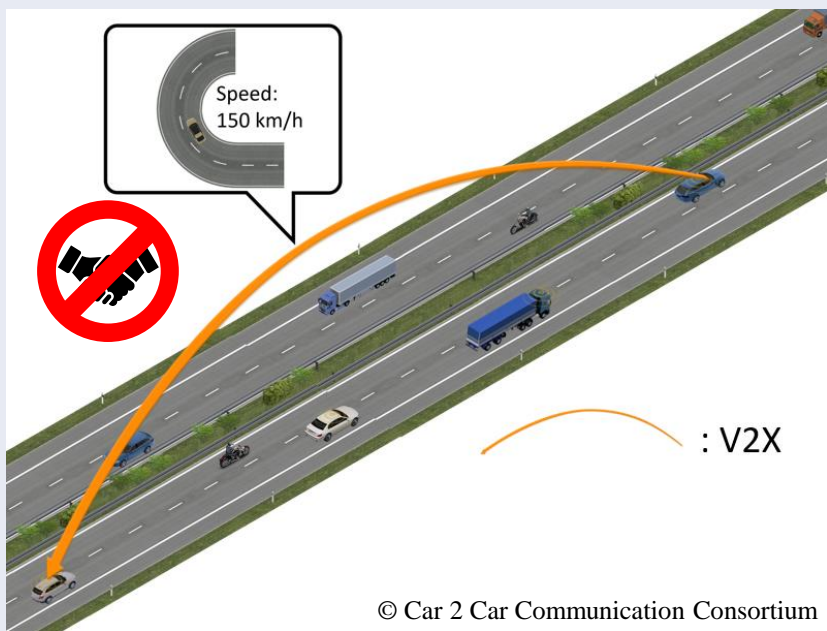
### Metadata

- Receiver shall be able to assess trustworthiness of the information by analyzing additional metadata
- Sender shall provide information about e. g.:
  - Sensors (algorithms) used to detect the hazard and their weighting (DENM)
  - General sender-abilities (sensors available, SAE level, ...) (CAM)
  - Weather
  - ...
- Metadata will be analyzed on receiver side, as the sender does not necessarily know, how information will be used



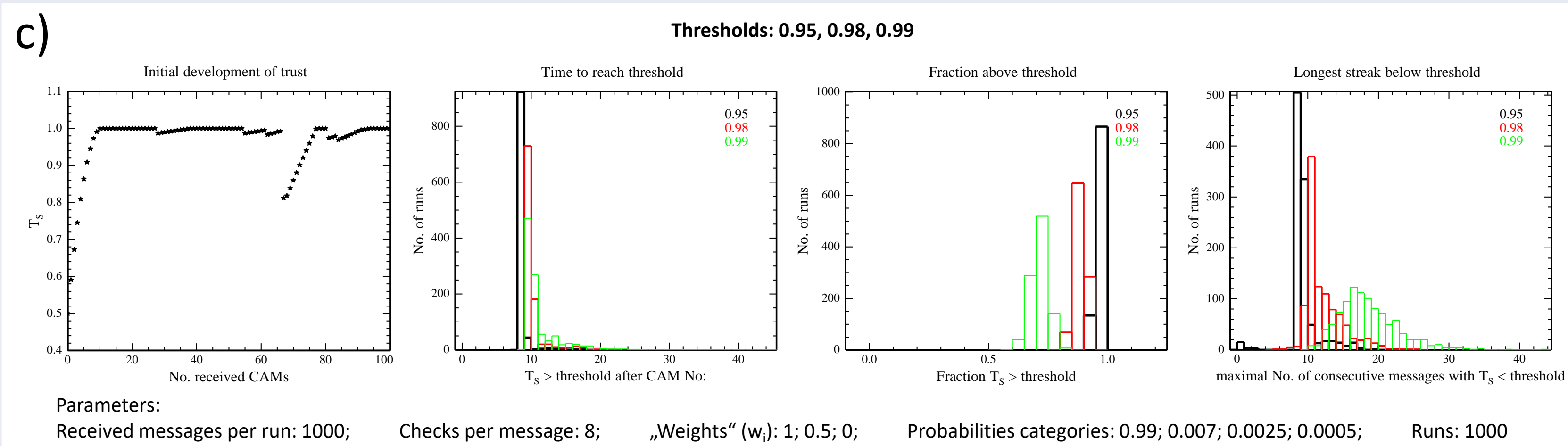
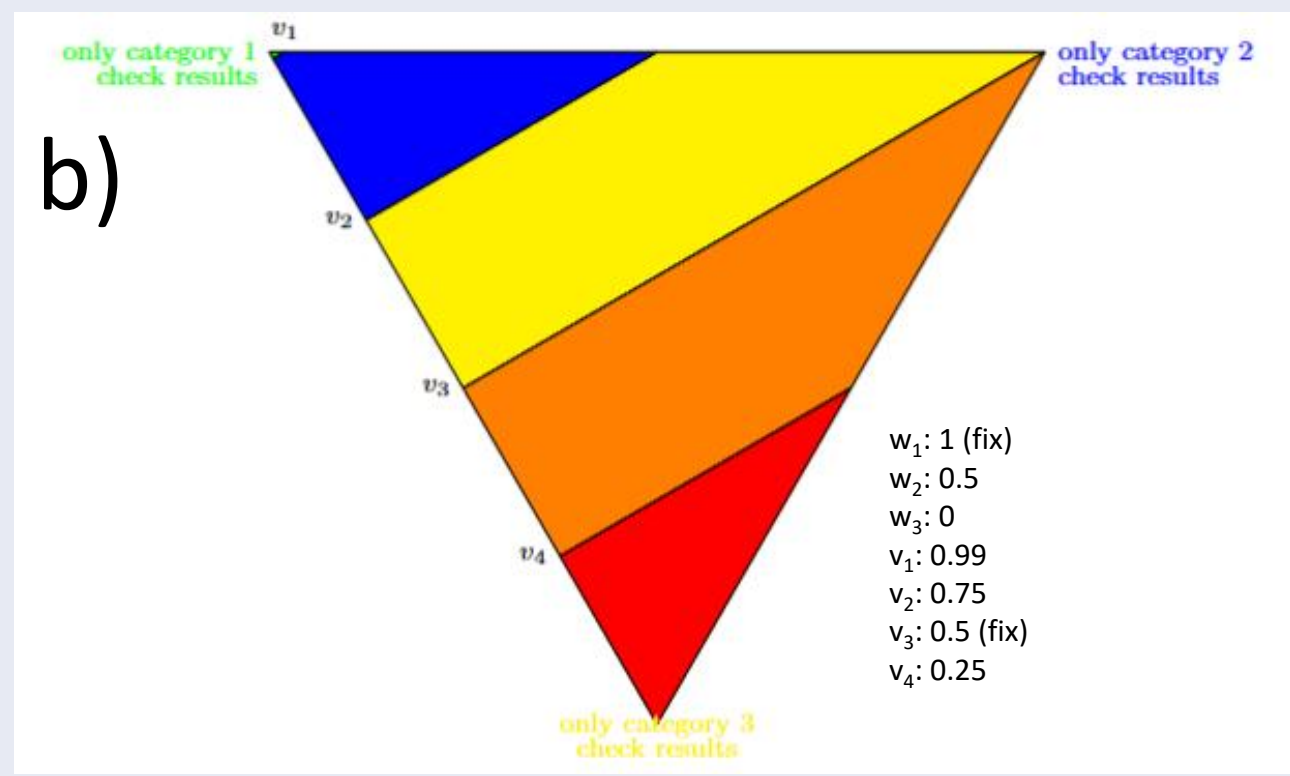
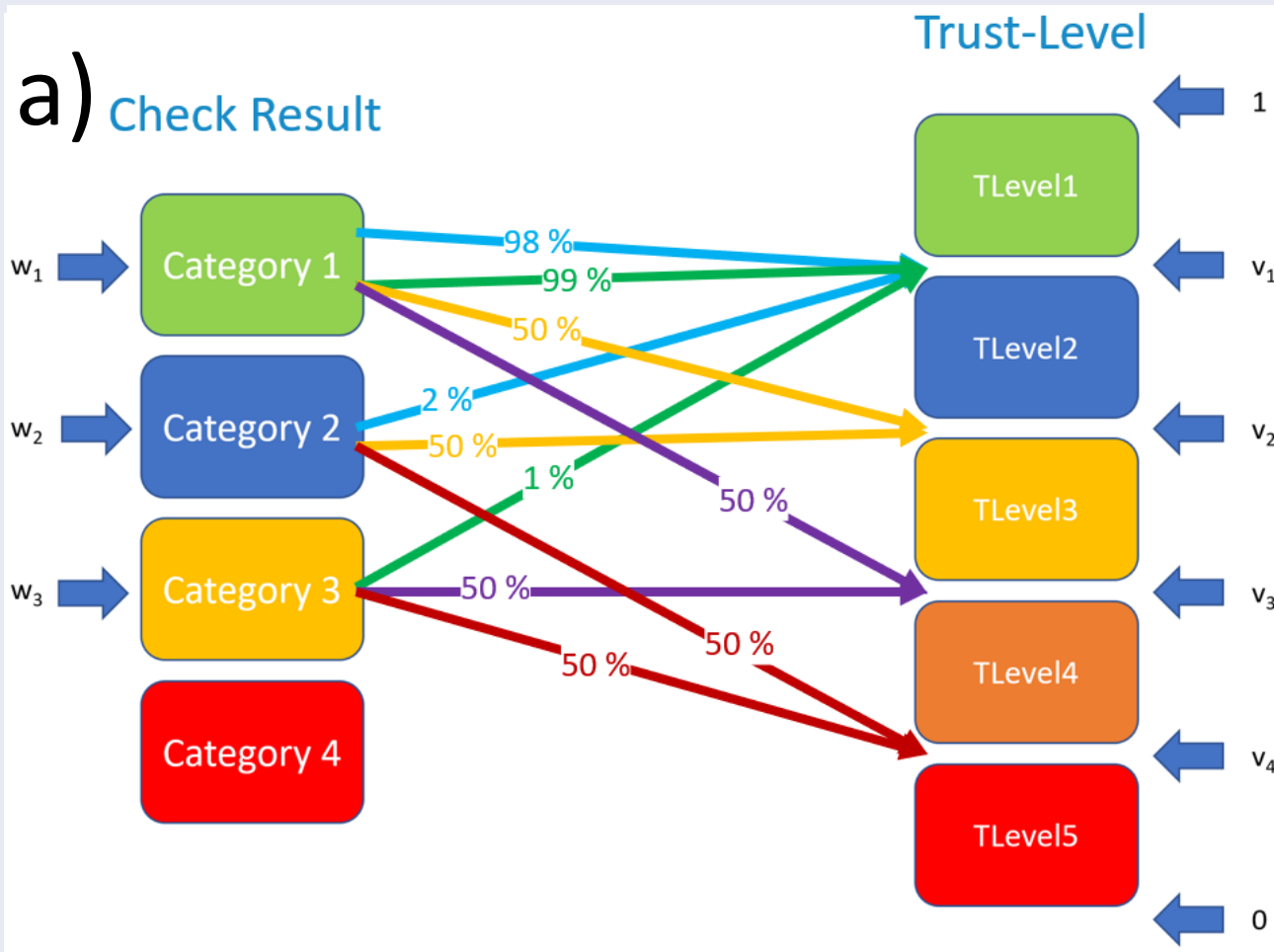
### Plausibility Checks

- Information received from other road users is checked for plausibility
- Only messages received from the road user to be trusted are considered
- Check results can be split into different categories, depending on how plausible they are
- Different possibilities to check plausibilities (see ETSI TS 103 759 – V2.1.1):
  - Single message (CAM or DENM)
  - Different messages (CAM and DENM)
  - Consecutive messages
  - Verification with internal sensors
  - Comparison with information already given (e. g.: HD-maps)
- Example "lateralAcceleration" (single message)
  - $x = |lateralAcceleration - speed^2 * curvature|$
  - $y = \frac{x}{maximum\ error\ (confidences)}$
  - Resulting category depending on y, e.g.:
    - $y \leq 1 \rightarrow Cat1$
    - $1 < y \leq 2 \rightarrow Cat2$
    - $2 < y \leq 5 \rightarrow Cat3$
    - $y > 5 \rightarrow Cat4$



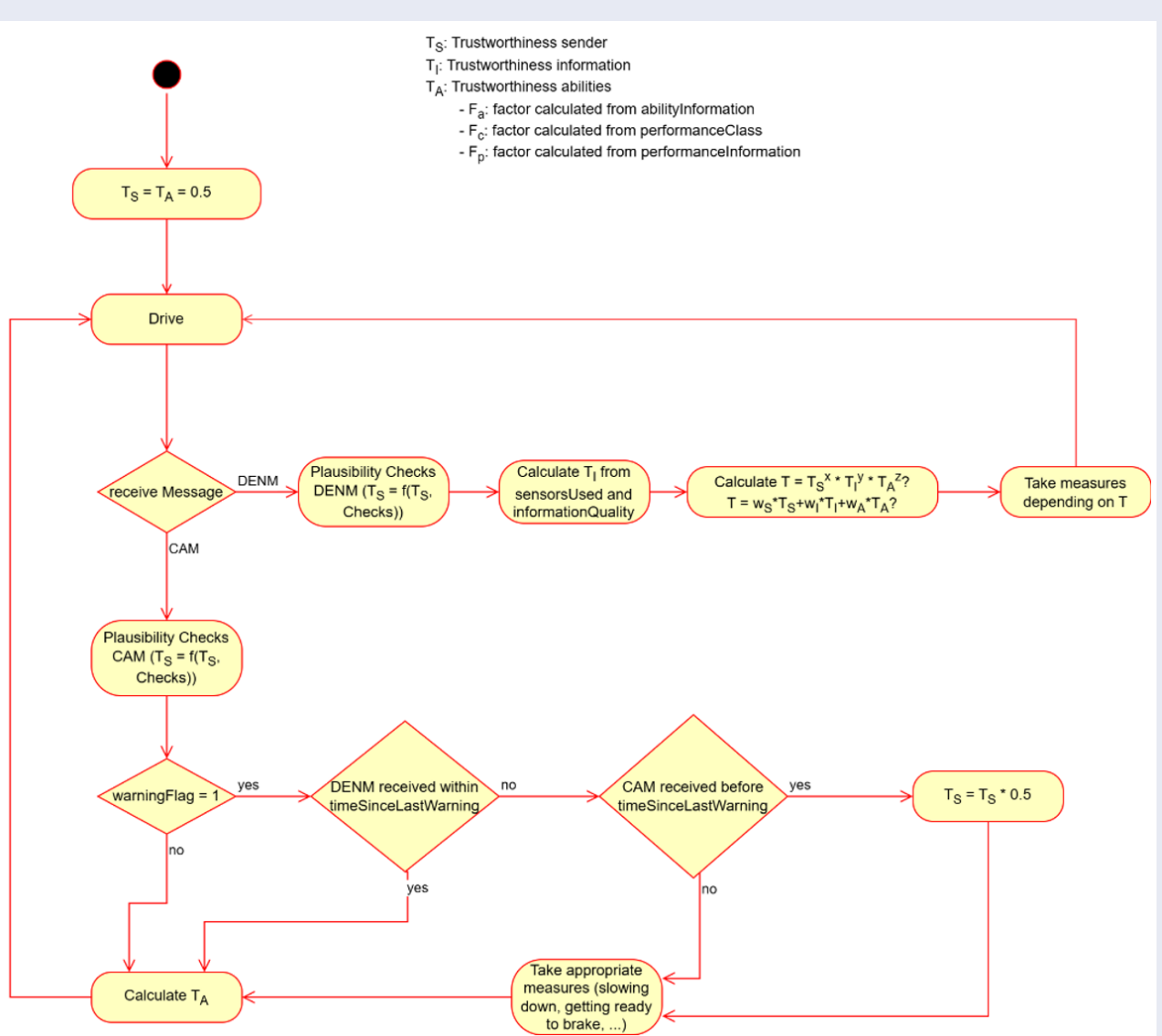
### Trust Model Plausibility

- Calculate trustworthiness ( $T_S \in [0,1]$ ) depending on the number of check results in different categories:
  - $T_S = \left( \frac{N_1}{M} w_1 + \frac{N_2}{M} w_2 + \frac{N_3}{M} w_3 \right) * \max\{1 - N_4, 0\}$ ;  
( $N_i$ : Categoryresults,  $M$ : Checks total)
- Using common sense/expert knowledge, define trust levels, reached depending on the ratio of results of different plausibility checks, e. g. (a):
  - 98 % Cat1 & 2 % Cat2  $\rightarrow$  TLevel1 ( $v_1$ )
  - 50 % Cat1 & 50 % Cat2  $\rightarrow$  Tlevel2 ( $v_2$ ), ...
- These ratios define equations for  $w_i, v_i$ :
  - $0.98 * w_1 + 0.02 * w_2 = v_1$
  - $0.5 * w_1 + 0.5 * w_2 = v_2, \dots$
- 7 parameters  $\rightarrow$  at least 7 equations needed
  - $w_i = v_i = x \in [0,1]$  simple solution  $\rightarrow$  fix 2 values:
- $\rightarrow$  We obtain  $T_S$ -values (or levels) for each combination of check results from Cat1 to Cat3 (b)
- $T_S$  shall build up over time and reach certain threshold (c)



### Summary Trust Mechanisms

- Trust in sender ( $T_S$ ), obtained from plausibility checks, will build up over time
- Trust-values based on metadata ( $T_A, T_I$ ) will be freshly calculated with every respective message received
- Total trustworthiness will be calculated from these values, if necessary with UC-dependent weightings of the different trustworthinesses
- There will be, also UC-dependent, different trustworthiness-thresholds for the usability of the provided information



### Message Extensions

- The checks mentioned above would profit massively from an extension of the messages used (CAMs, DENMs)
- Some fields are currently "optional", some have to be added
- Consider trade off bandwidth  $\leftrightarrow$  benefit

	Original Size [bit]	Extension [bit]	Extension [%]
CAM (most) probable	360-5661	50	1-14
CAM all		104	2-29
DENM (most) probable	317-77622	55	0.1-17
DENM all		261	0.3-82

	what	where	description	size [bit]	probability of use
new	"000"	CAM	Information on which warning-use cases might be handled by the sending station; might be a hinting to identify possible cause codes	24	perhaps
	"warning" flag	CAM	A single bit, indicating whether the station is currently sending DENMs	1	most probable
	timeSinceLastWarning	CAM	Time in ms since the last DENM was sent	10	probable
	abilityInformation	CAM	Information on which driving assistants (or SAE levels) are available	107	probable
	performanceInformation	CAM	Information on which driving assistants (or SAE levels) are currently active	107	probable
	detectionInformation	CAM	Information, which sensors are available for this station	19	probable
	algorithmUsed	DENM	Information on which algorithms are used for object detection and sensor fusion	107	rather improbable
	sensordetected	DENM	A list of sensors (e.g.: Lidar, Camera, Radar, ...) used to detect the event, with an information quality (between 1% and 100%)	11/sensor	probable
	lateralAcceleration	CAM	Acceleration perpendicular to direction of movement, with confidence	16	perhaps
	performanceClass	CAM	Describes the age of data used for the cam	7	perhaps
optional	accelerationControl	CAM	gives pedal states or longitudinal driving assistants active	7	rather improbable
	lanePositionInfo	DENM	gives information on which lane(s) the current event is located	4+38	improbable
	eventSpeed	DENM	gives information on the speed of an event, with confidence	21	rather improbable
	eventPositionHeading	DENM	gives information on the heading of a moving event, with confidence	19	rather improbable
	transmissionInterval	DENM	Time between two DENM transmissions	14	perhaps