Chapter 10: A Review of Information Dissemination Protocols for Vehicular Ad Hoc Networks

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Outline

- Abstract
- Introduction
- Multi-Hop Broadcasting
- Single-Hop Broadcasting
- Performance Evaluation
- Summary And Open Issues

Abstract

- Traffic information will be collected and disseminated in real-time by mobile sensors instead of fixed sensors used in the current infrastructure-based traffic information systems.
- A distributed network of vehicles such as a vehicular ad hoc network (VANET) can easily turn into an infrastructure-less self-organizing traffic information system.
- Vehicle can participate in collecting and reporting useful traffic information such as section travel time, flow rate, and density.

Introduction

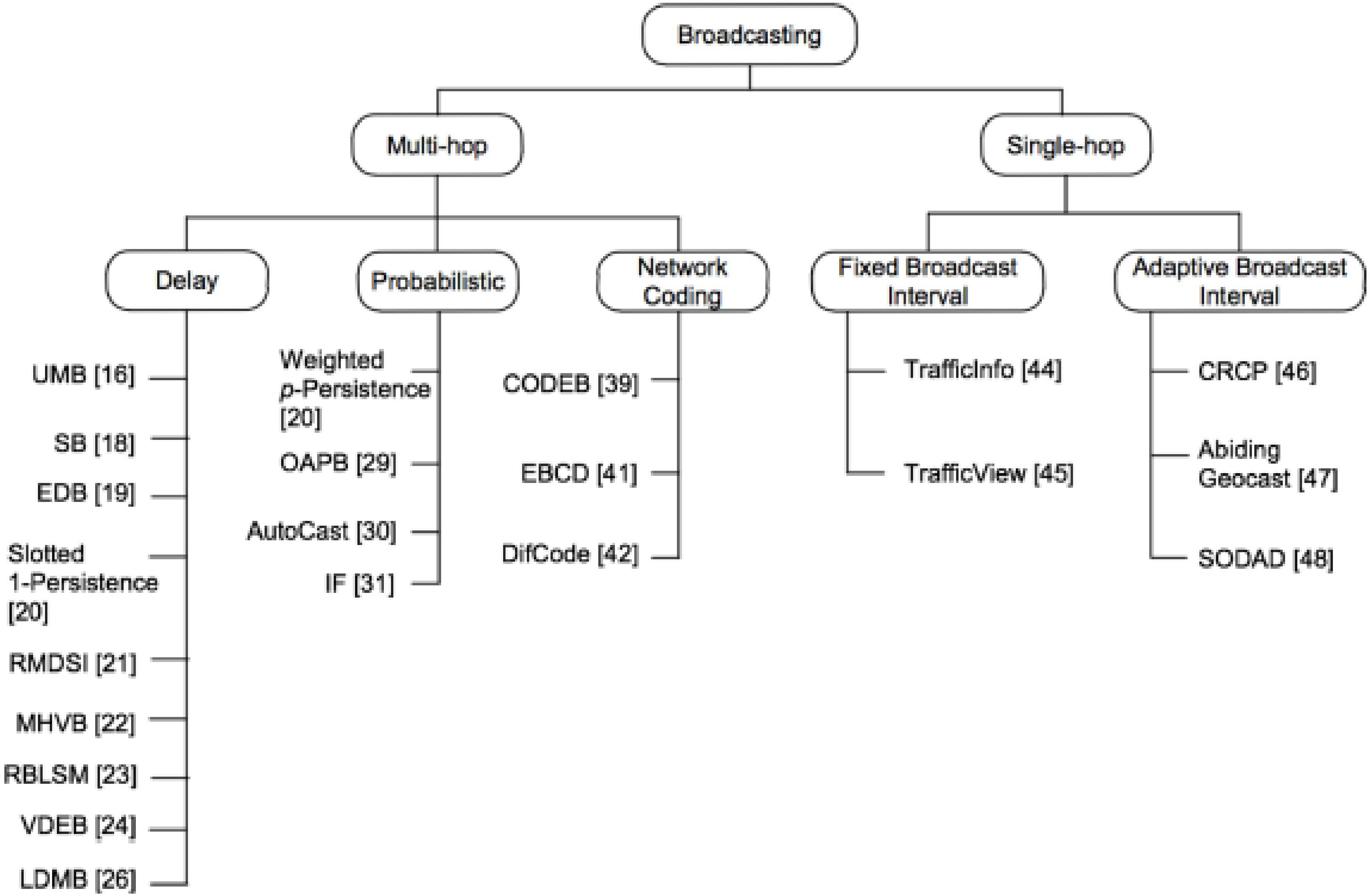
- Any vehicle can become a mobile sensor, participating in collecting and disseminating useful traffic information.

- VANETs
  - Multi-hop Broadcasting
  - Single-hop Broadcasting

Introduction (Cont.)

- Multi-hop Broadcasting
  - Packet propagates through the network by way of flooding.

- Single-hop Broadcasting
  - Keeps the information in its on-board database.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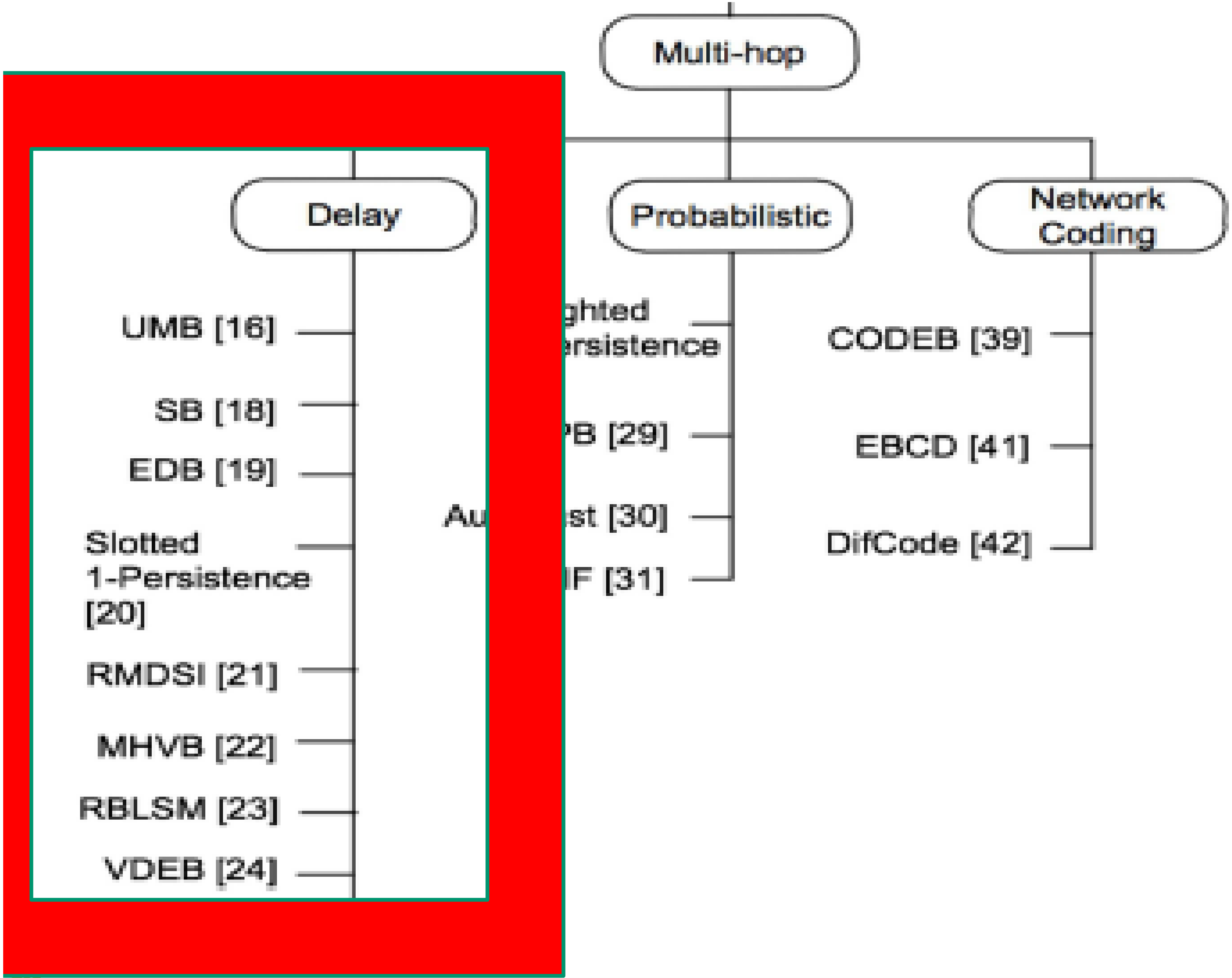
Multi-hop Broadcasting

- A pure flooding scheme, where every single vehicle rebroadcasts the packet, is inefficient because of two main reasons inefficient of two main reasons:
  - Scalability
  - Packet collision
- A good multi-hop broadcasting protocol must be able to resolve these issues.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Delay-Based Multi-hop Broadcasting

- The vehicle with the shortest waiting delay gets the highest priority in rebroadcasting the packet.

Urban Multi-hop Broadcast (UMB)

- Designed to solve the broadcast storm ,the hidden node, and the reliability problems.

- Divides a road inside the transmission range of a transmitter into small segments, and it gives the rebroadcast priority to the vehicles that belong in the farthest segment.

Urban Multi-hop Broadcast (UMB)

- Two types of packet forwarding :
  - Directional broadcast
  - Intersection broadcast

Directional broadcast

- Request-to-Broadcast(RTB):includes its own position and the direction of packet propagation.
- Once the vehicles in the transmission range of the transmitter receives the RTB packet ,each of them starts transmitting a jamming signal called blackburst for a specified period of time.
- Black-burst duration

$$L = \left\lfloor \frac{d}{R} \times N_{\max} \right\rfloor \times S$$

L:black-burst duration

d:distance between the vehicle and the transmitter

R :transmission range

Nmax : number of road segments inside the transmission range

Directional broadcast

- Clear-to-Broadcast (CTB): if the vehicle finds the channel idle after its black-burst transmission, it transmits a control packet .
- Whole process :

  RTB=>CTB=>DATAACK

- Not a collision-free protocol.

Smart Broadcast (SB)

- Improve the limitation of UMB
- RTB=> other receive the RTB and determine the "sector"=> chooses a contention delay based on the sector that it resides

$$W_r = \{(r-1)cw, (r-1)cw+1, \ldots, rcw-1\}$$

r = 1, 2, . . .,Ns;   cw: duration of contention windows

=>CTB=>DATA

- Reduces packet collision.
- SB outperforms UMB ：
  - UMB have a higher number of collisions when the vehicle density increases.

Efficient Directional Broadcast (EDB)

- Similar UMB and SB protocols
- RTB and CTB are not used
- Use of directional antennas
- Two types of packet forwarding:
  - Directional broadcast on the road segment
  - Directional broadcast at the intersection

Efficient Directional Broadcast (EDB)

- To reduce the number of redundant rebroadcast packets, EDB assigns a different waiting time before rebroadcasting to each vehicle within the range of the transmitter.

$$W = \left(1 - \frac{d}{R}\right) maxWT$$

R : transmission range

D: distance between the vehicle and the transmitter

maxWT : maximum waiting time

- A vehicle that is farther away from the transmitter will be given a higher rebroadcast priority.

Efficient Directional Broadcast (EDB)

- After its waiting time expires=>immediately transmits an ACK packet=>data
- Two other variations
  - Random Directional Broadcast(RDB)
  - Simple Distance-based Directional Broadcast (SDDB)

- EDB protocol performs better :
  - EDB has a higher packet delivery ratio is that it can reduce packet collision through the use of ACK packets.

Slotted 1-Persistence Broadcasting

- Priority is given to the vehicles that are farther away from the transmitter.
- A vehicle receives a packet, it rebroadcasts the packet according to an assigned time slot.

$$T_{S_{ij}} = S_{ij} \times \tau$$

τ :estimated one-hop propagation and medium access delay

Sij : assigned slot number

$$S_{ij} = N_s \left(1 - \left\lceil \frac{\min(D_{ij}, R)}{R} \right\rceil \right)$$

Dij : distance between transmitter i and vehicle j,

R : transmission range Ns : pre-determined number of slots.

- Solving the reliability problem when the network becomes disconnected.
- Similar to EDB, when a vehicle receives a packet, it computes a waiting time before rebroadcasting the packet according to the function

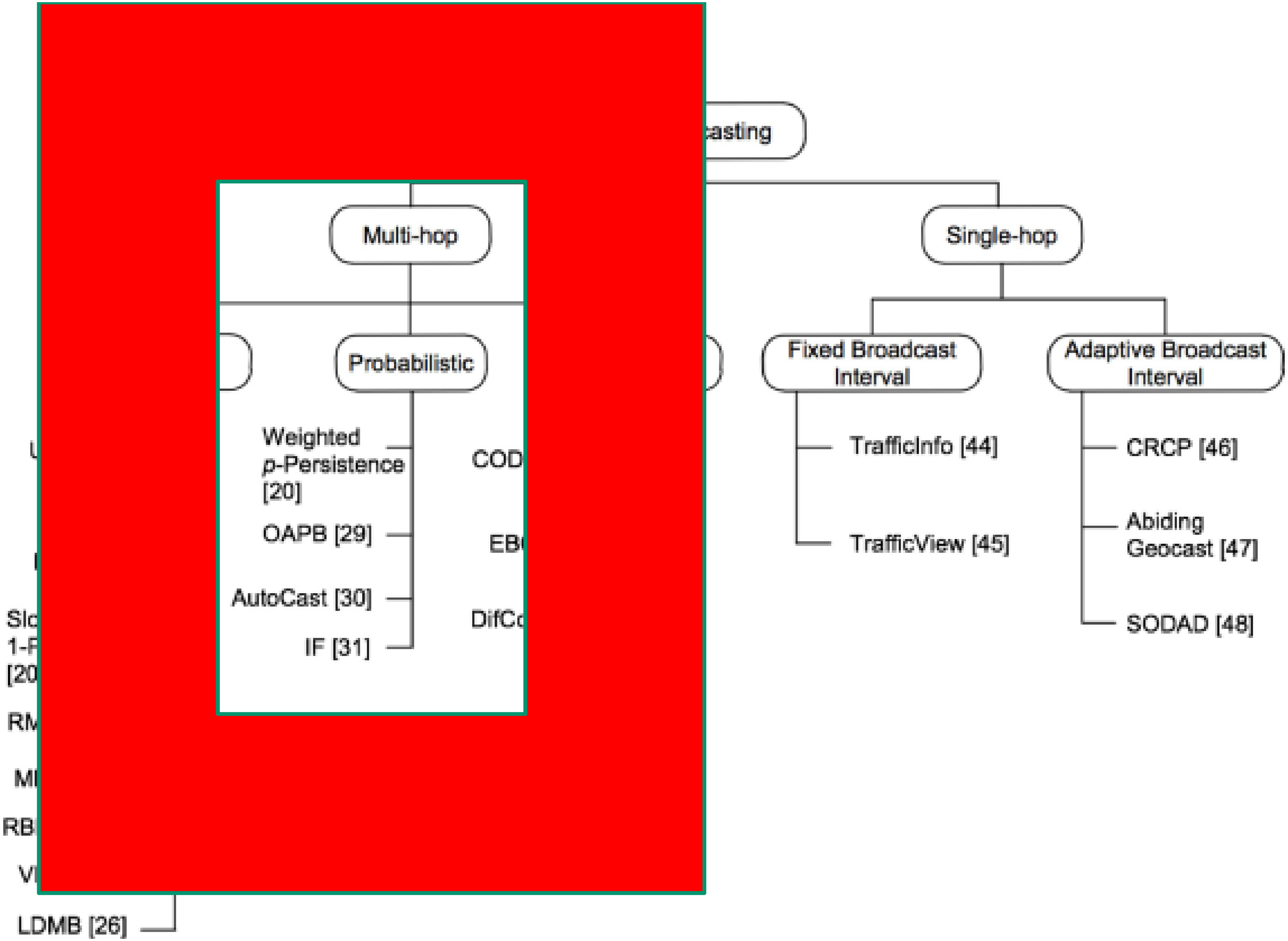
Multi-hop Vehicular Broadcast (MHVB)

- When a vehicle receives a packet, it computes the waiting time before rebroadcasting the packet based on the distance between itself and the transmitter.

- Has a traffic congestion detection feature.

Reliable Broadcasting of Life Safety Messages (RBLSM)

- After receiving a packet from the source, each node in the transmission range of the source determines its waiting time before rebroadcasting the packet.
- This protocol the priority is given to the vehicle nearest to the transmitter.
- More reliable than the vehicles that are farther away from the transmitter.
- Use of the RTB and CTB control packets.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Probabilistic-based Multi-hop Broadcasting

- An optimal probability assignment function.
- A pre-defined fixed value for the forwarding probability.
- Forwarding probability dynamically based on factors such as vehicle location and network density

Weighted p-Persistence

- A vehicle that receives a packet for the first time computes its own rebroadcast probability based on the distance between itself and the transmitter.

$$p_{ij} = \frac{D_{ij}}{R}$$

Dij: distance between transmitter i and vehicle j

R :transmission range

- Rebroadcast packets can still be large if the network is dense.

Optimized Adaptive Probabilistic Broadcast (OAPB)

- To select an appropriate forwarding probability

$$\overline{\phi} = \frac{P_0 + P_1 + P_2}{3}$$

P0, P1, and P2 are functions of the number of one-hop neighbors

- Each rebroadcast vehicle that has the same forwarding probability φ will be assigned a different delay.

$$\Delta(t) = \Delta(t)_{\max} \times (1 - \overline{\phi}) + \delta$$

Δ(t)max : maximum delay time δ : random variable

- OAPB outperforms DB in terms of broadcast overheads and broadcast delivery ratio.

AutoCast

- The rebroadcast probability is calculated from the number of neighbors around the vehicle.

- In this protocol, a packet is also rebroadcasted periodically.

N:number of one-hop neighbors

$$p = \frac{2}{N_h \times 0.4}$$

α : constant specifying the desired number of broadcast packets per second

$$t = N_h/\alpha$$

Irresponsible Forwarding (IF)

- Assigns the forwarding probability based on the distance between the vehicle and the transmitter as well as the vehicle density.

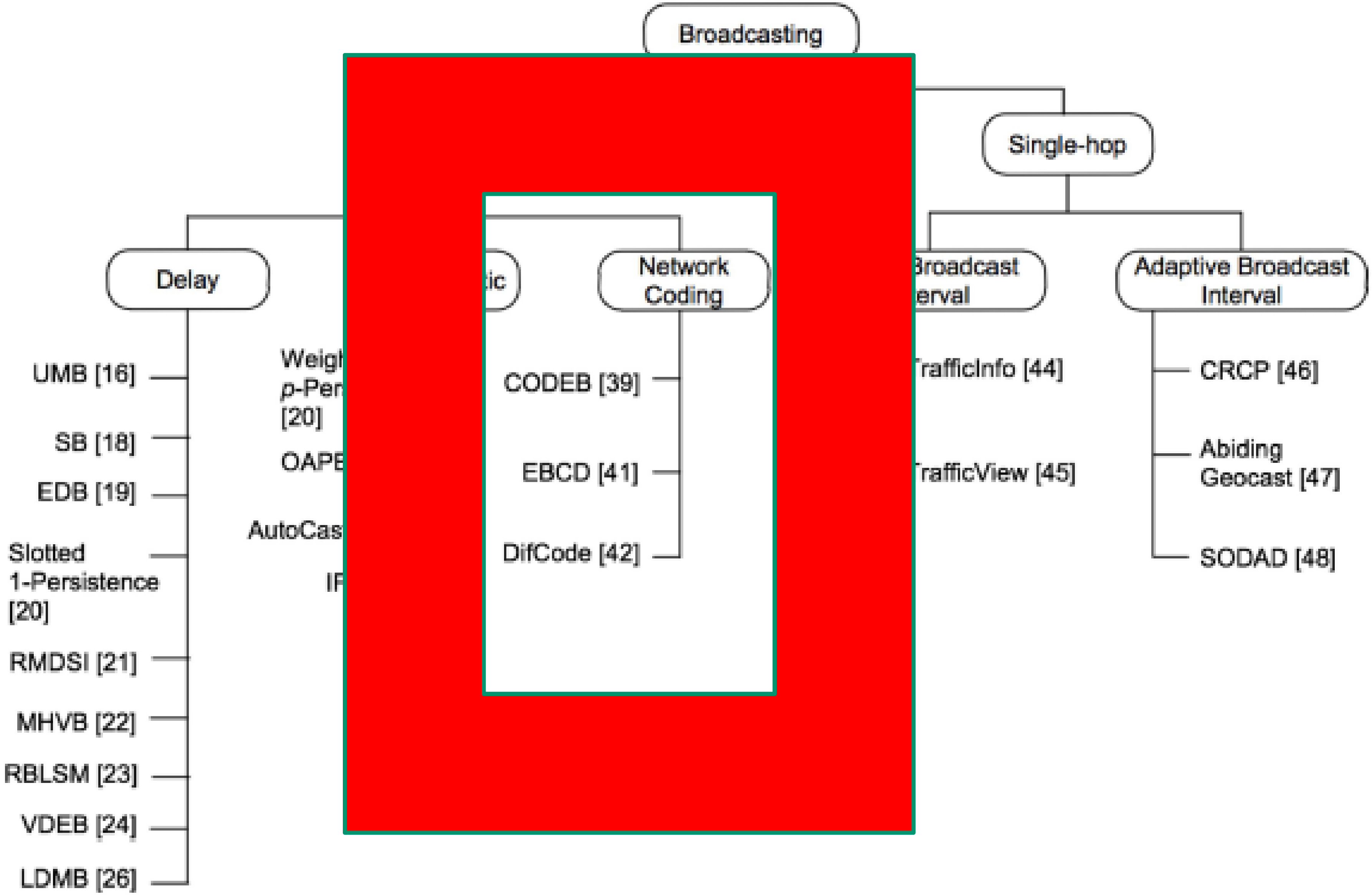
$$p = e^{-\frac{\rho_S(z-d)}{c}}$$

Ps : vehicle density

z : transmission range

d : distance between the vehicle and the transmitter

c ≥ 1 is a coefficient which can be selected to shape the rebroadcast probability.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Network Coding-Based Multi-hop Broadcasting

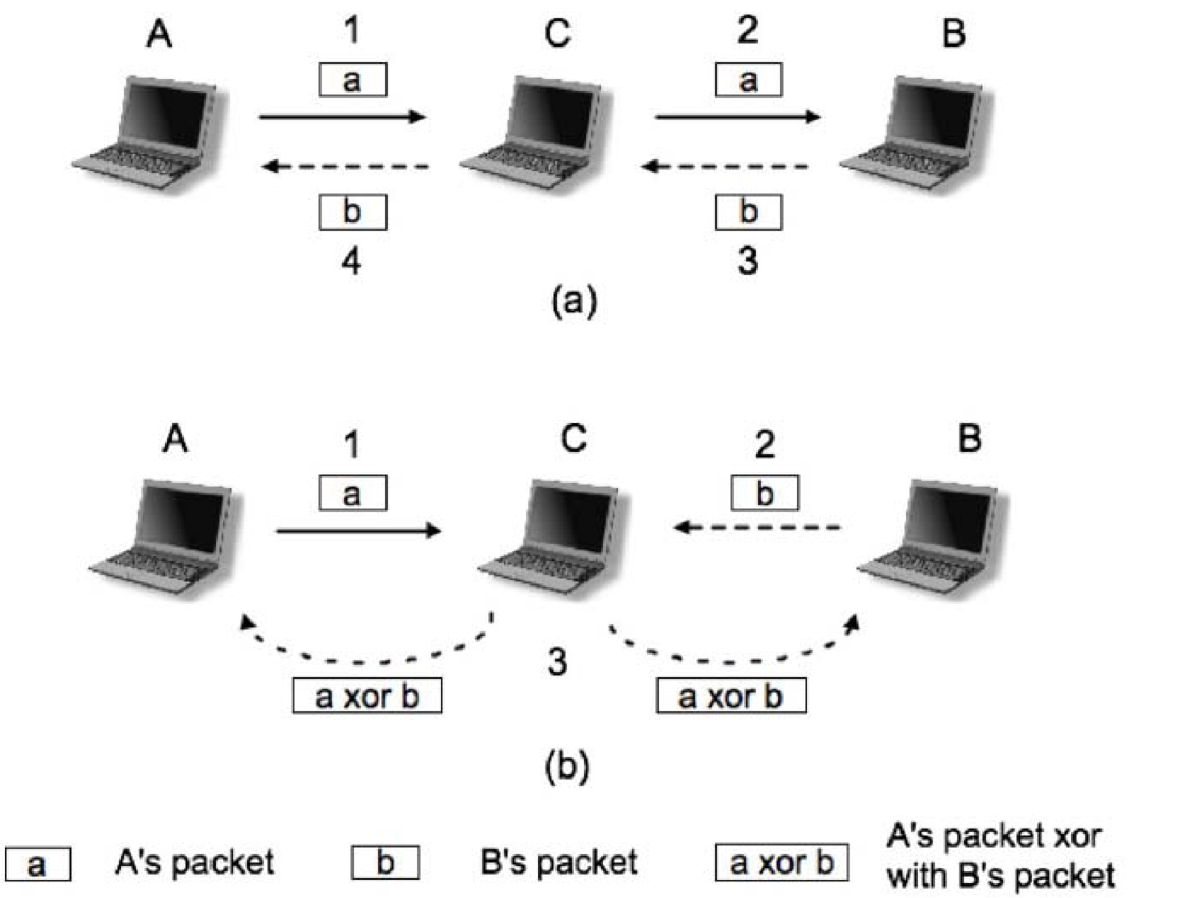


Fig. 2. (a) Example of traditional transmission (b) Example of network coding-based transmission.

COPE

- Unicast routing protocol
- Three key techniques:
  - Opportunistic listening
  - Opportunistic coding
  - Neighbor state learning

CODEB

- Relies on opportunistic listening
- Each node also periodically broadcasts a list of its one-hop neighbors
- Relies on opportunistic coding

Efficient Broadcasting Using Network Coding and Directional Antennas (EBCD)

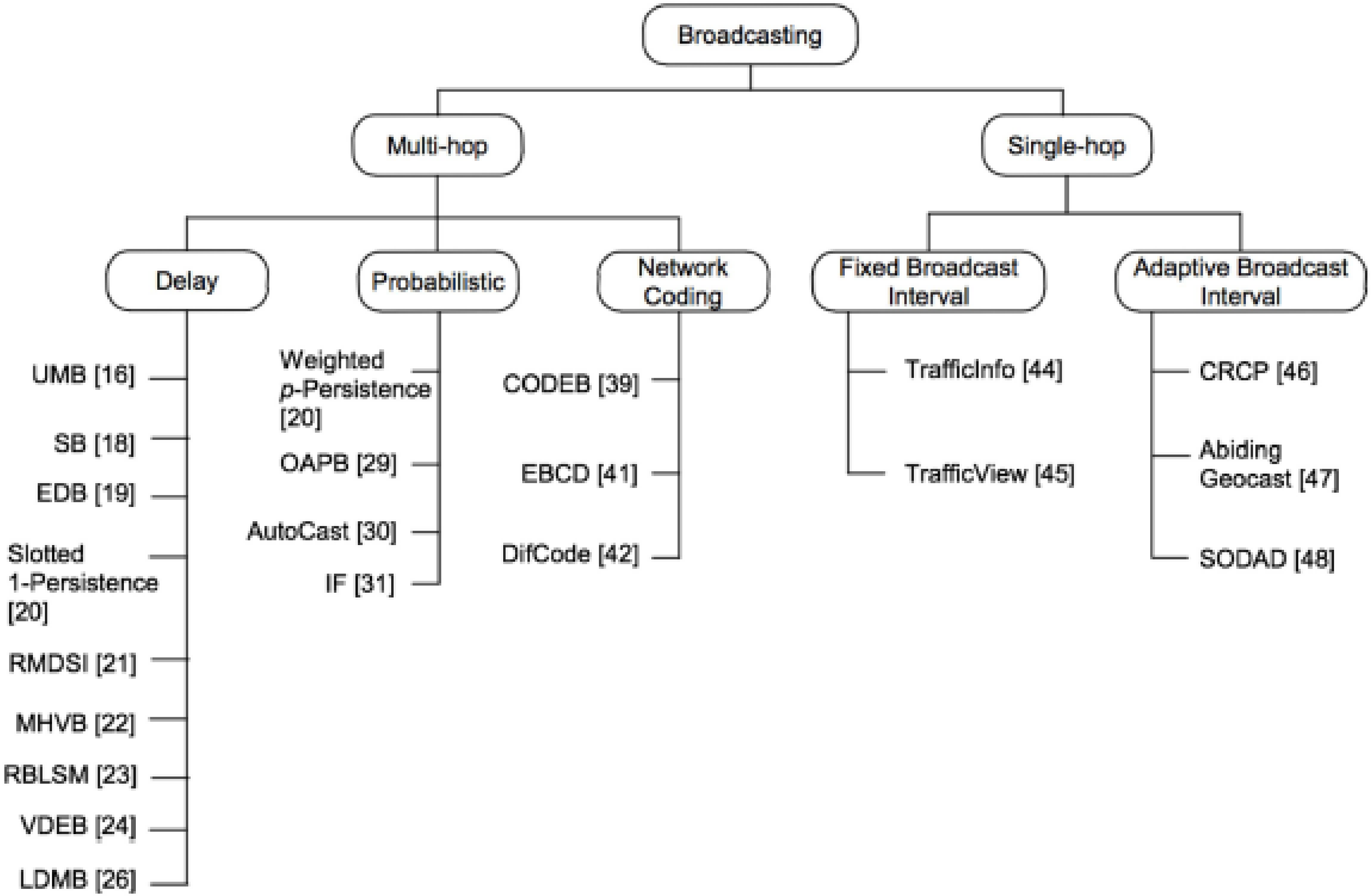
- Combines the advantage of network coding with that of directional antennas
- EBCD uses a algorithm called Dynamic Directional Connected Dominating Set (DDCDS)

DifCode

- Reduce the number of transmissions required to flood packets in an ad hoc wireless network
- Selects the next forwarding nodes deterministically
- Selection algorithm based on multi-point relay

(MPR)

- Buffers for keeping three types of packets:
  - Successfully decoded packets
  - Not immediately decodable packets
  - Packets that need to be encoded and broadcasted further



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Single-Hop Broadcasting

- Need to be considered:
  - Broadcast interval
  - Information that needs to be broadcasted

- Divide the single-hop broadcasting protocols into two categories:
  - Fixed broadcast interval protocols
  - Adaptive broadcast interval protocols

TrafficInfo

- Each vehicle in the network periodically broadcasts the traffic information stored in its database.
- The relevance of the information is determined by a ranking algorithm

TrafficView

- Is a single-hop broadcasting
- Two aggregation algorithms:
  - Namely the ratio-based algorithm and the cost based algorithm
  - Ratio-based algorithm

Collision Ratio Control Protocol (CRCP)

- Each vehicle disseminates the traffic information periodically
- Three methods for selecting the data:
  - Random Selection (RS)
  - Vicinity Priority Selection(VPS)
  - Vicinity Priority Selection with Queries(VPSQ).

Abiding Geocast

- Designed for disseminating safety warnings within an effective area where these warnings are still relevant and applicable.

- Roads are divided into segments of known length. Each vehicle collects the data on its current segment either by sensing the information itself or observing what the other vehicles report.
- Reduce the number of redundant rebroadcast packets:
  - Provocation
  - Mollification

Performance Evaluation

- These protocols are often evaluated by different performance metrics
- Suggest a new unified metric that is capable of giving a protocol a fair overall evaluation.

Existing Metrics

- How frequently the information packets are duplicated
- How far the information packets can propagate
- How fast the information can be spread.

Broadcasting Type	General Characteristics	Advantages	Disadvantages
Multi-hop	• *Packets are disseminated by ways* of smart flooding • *Reduce redundancy by varying* broadcast probability or delay	• *Packets can be disseminated quickly* • *Good for safety alerts and emergency* warning applications • *No need for large storage space to* keep unbroadcast packets	• *Need an algorithm to deal with* the broadcast storm problem • *No packet persistency*
Single-hop	• *Packets are disseminated by ways* of periodic broadcast • *No packet flooding* • *Reduce redundancy by varying* the broadcast period of each node • *Rely on node mobility to carry* and spread the information	• *Good for applications that need* packet persistency • *No broadcast storm*	Packet dissemination speed may be slow • *Not suitable for delay-sensitive* applications • *May require large storage space* to keep unbroadcast information

TABLE II
EXISTING PERFORMANCE METRICS FOR AN EVALUATION OF BROADCASTING PROTOCOLS.

Domain	ID	Metric Name	Mathematical Definition	Description	Unit	Favorable Value
Frequency	1	Redundancy rate	$\frac{\text{no. of duplicate packets}}{\text{no. of source packets}}$	Measure the number of duplicate packets per one source packet	unit-less	Low
	2	Load generated per broadcast packet	$\frac{\text{no. of bits transmitted}}{\text{no. of source packets}}$	Measure the total number of bits used in broadcasting one source packet	bit/pkt	Low
	3	Forward node ratio	$\frac{\text{no. of vehicles forwarding the packet}}{\text{no. of vehicles in the network}}$	Measure the proportion of vehicles in the network that rebroadcast the source packet	unit-less	Low
	4	Link load	$\frac{\text{no. of broadcast bits received by a vehicle}}{\text{observation period}}$	Measure amount of broadcast traffic received at each vehicle over unit time	bit/s	Low
	5	Broadcast overhead	$\frac{\text{no. of duplicate packets received by a vehicle}}{\text{no. of vehicles in a defined zone}}$	Measure the number of packets collectively duplicated in a defined area	pkt/veh	Low
	6	Delivery ratio, Success ratio	$\frac{\text{no. of vehicles successfully receiving packets}}{\text{no. of vehicles in the network}}$	Measure the proportion of vehicles that successfully receive the broadcast packets	unit-less	High
	7	Reception rate, Reachability	$\frac{\text{no. vehicles receiving the broadcast packets}}{\text{no. of vehicles reachable by pure flooding}}$	Compare the reachabiltiy of a broadcasting protocol to that of the pure flooding protocol	unit-less	High
	8	Saved rebroadcast	$\frac{\text{no. receiving host - no. transmitting hosts}}{\text{no. hosts receiving packet}}$	Measure the number of saved rebroadcast packets	unit-less	High
	9	Collision ratio, Packet loss ratio	$\frac{\text{no. of collision packets}}{\text{no. of transmitted packets}}$	Measure the rate at which the collision occurs	unit-less	Low

Space	10	Propagation distance	| Packet last position - Packet initial position |	Measure the distance between the origin of the packet and the point where it is last received	m	High
	11	Forward progress, One-hop progress	| Position of next rebroadcast vehicle - Position of current transmitter |	Measure the additional distance covered by the packet when it is rebroadcasted	m	High
	12	Number of hop propagated	Last hop the packet is received - Packet origin	Measure the number of hops that the packet can traverse	hops	High
	13	Sustainable number of hops	Last hop the packet is received with required QoS - Packet origin	Measure the number of hops that the packet can traverse with the desired quality	hops	High
Time	14	Propagation time, End to end delay	The instant the packet is received at a specific point - The instant the packet is originated	Measure the time it takes a packet to traverse from a source to a specific point in the network	s	Low
	15	Rebroadcast latency	The instant the packet is received by the next vehicle - The instant the packet is broadcasted by current vehicle	Measure the time until the packet is received successfully by the next vehicle	s	Low
Mixed	16	Propagation speed, Dissemination speed	$\frac{\text{Packet propagation distance}}{\text{Propagation delay}}$	Measure the rate at which the packet can propagate per unit time	m/s	High

Suggested Metric

TABLE III
BROADCASTING PROTOCOLS IN VANETS AND THE METRIC DOMAINS USED FOR EVALUATION.

Broadcasting Type	Protocols	Evaluation Models	Simulation Platforms	Metric Domains			
				Frequency	Space	Time	Mixed
Multi-hop	UMB [16]	Simulation	MATLAB [49], CSIM [50]	2, 6			16
	SB [18]	Analysis & Simulation	MATLAB		11	15	16
	EDB [19]	Simulation	Proprietary	3, 6			
	Slotted 1-Persistence [20]	Simulation	OPNET [51]	4, 7, 9	12	14	
	Weighted p-Persistence [20]	Simulation	OPNET	4, 7, 9	12	14	
	RMDSI [21]	Simulation	NS-2 [52]	6		14	
	MHVB [22]	Simulation	NS-2	6, 9			
	RBLSM [23]	Simulation	MATLAB			15	
	VDEB [24]	Simulation	NS-2	1		14	
	LDMB [26]	Simulation	Unspecified	6		14	
	OAPB [29]	Simulation	NS-2	5, 6		14	
	AutoCast [30]	Simulation	NS-2	6			16
	IF [31], [34]	Analysis & Simulation	MATLAB, NS-2	1, 7, 8		14	
	CODEB [39]	Simulation	NS-2	6			
	EBCD [41]	Simulation	NS-2	1, 6			
	DifCode [42]	Simulation	OPNET	1			
Single-hop	TrafficInfo [44]	Simulation	STRAW/SWANS [53]	6			
	TrafficView [45]	Simulation	NS-2		10		
	CRCP [46]	Simulation	NETSTREAM [54]	9			
	Abiding Geocast [47]	Simulation	OMNeT++ [55]	5			
	SODAD [48]	Simulation	NS-2	9		14	

Suggested Metric

- A new metric Dissemination Efficiency(DE)

$$DE = \frac{\text{Propagation Distance} \times \text{Success Ratio}}{\text{Propagation Time} \times \text{Redundancy Rate}}.$$

  propagation distance : measured in meters

  propagation time :measured in seconds

  redundancy rate and the success ratio are unitless

  DE has a unit of m/s

- Dissemination Efficiency combines the metrics in all the three independent domains
- DE value increases if the information can be distributed farther ,faster, with high success rate, and with less redundancy.

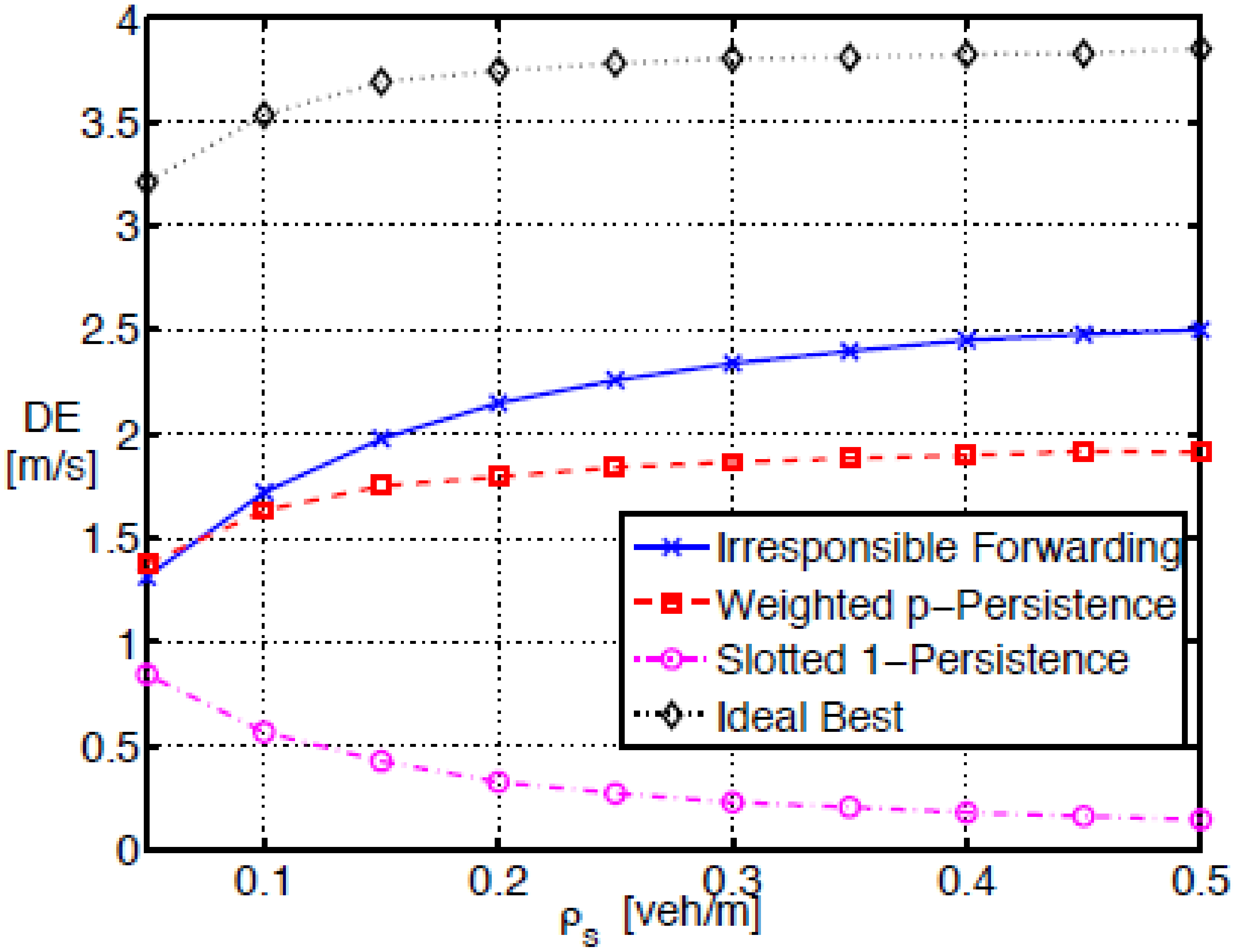

Fig. 3. Dissemination efficiency as a function of vehicle density.

Summary And Open Issues

- Most of the protocols are evaluated only by simulation.
- The dynamics of packet forwarding should be modeled in the theoretical framework.
- Broadcasting protocols still need a thorough test under more complex interconnected road structures

Homework #10:

1. Why network coding-based transmission fast then traditional transmission?
2. What is DE function?