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Unicast routing protocols for urban vehicular networks: review, taxonomy, and open research issues

Key words: unicast protocols, taxonomy, protocol review, vehicular ad hoc networks, geographic routing

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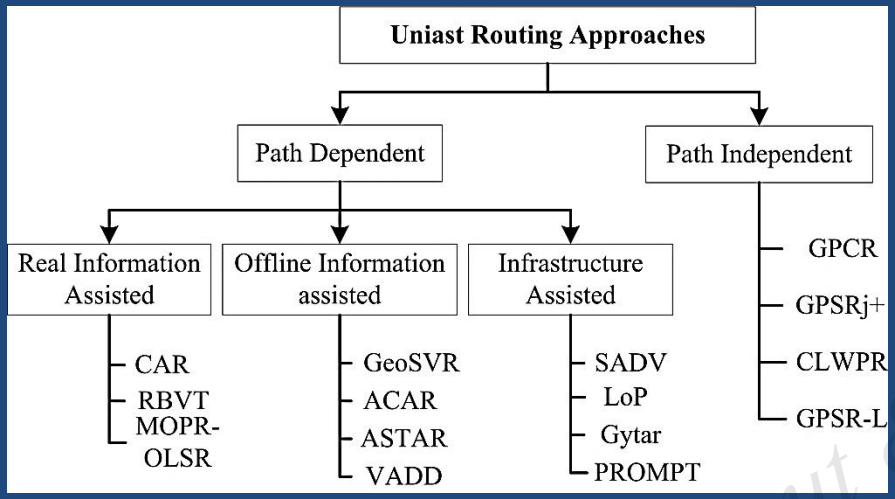
Introduction

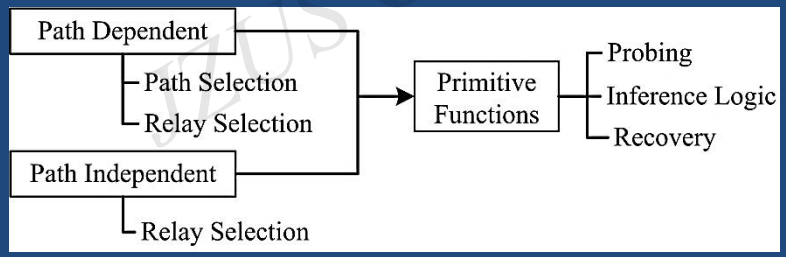
- VANET: A communication network comprising vehicles or roads

- Primary focus of ITS is safety-related applications
  - Represents public interest
  - Requires dissemination techniques
- Secondary application area is non-safety/infotainment
  - Represents individual interest
  - Requires techniques for point-to-point link establishment
- Network constraints represent complexities for unicast protocols
  - Route discovery
  - Mobility management
  - Recovery strategies

Initial Classification Based on Routing Approaches



Primitive Functions in Path and Relay Selection

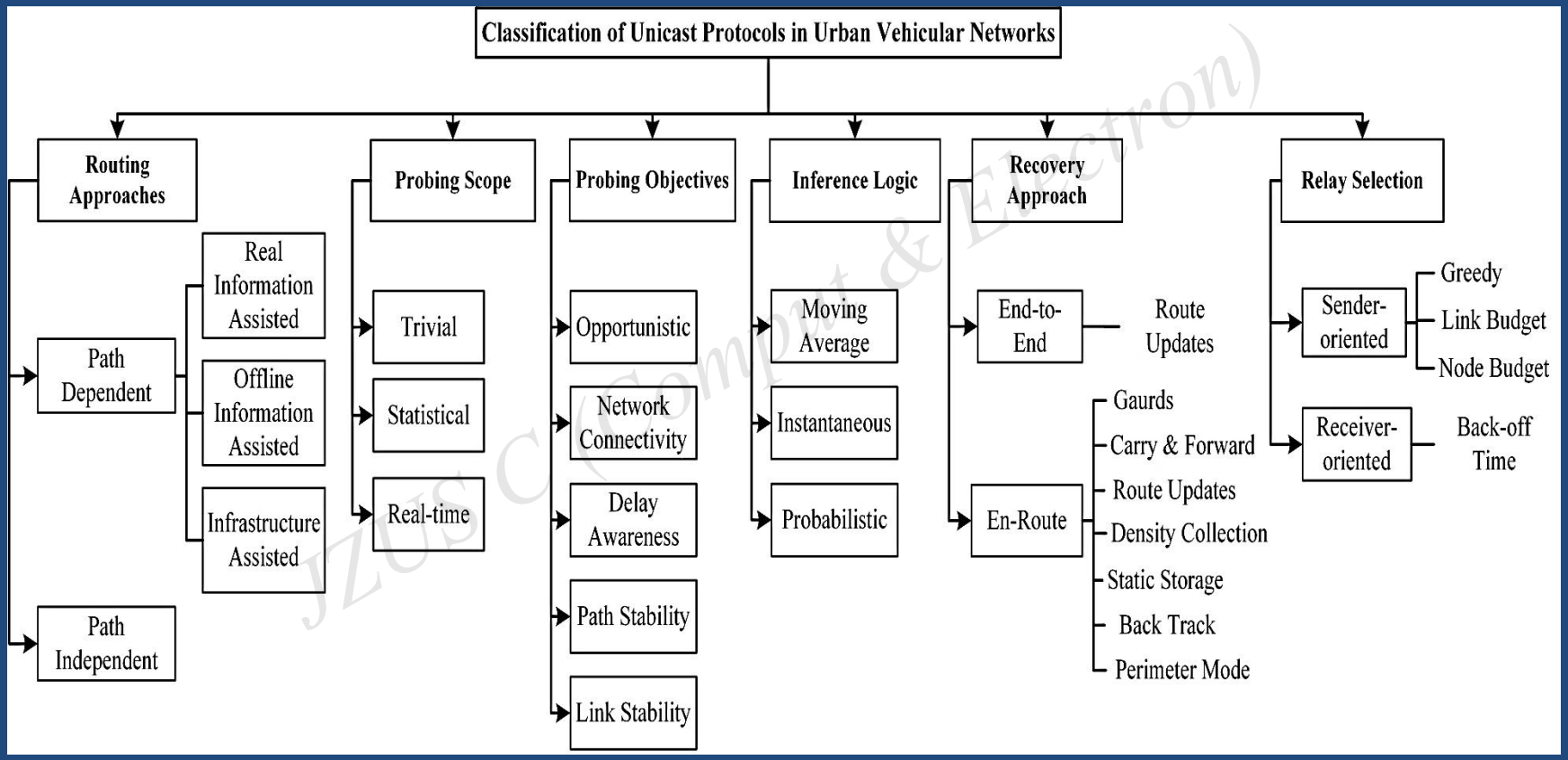


Primitive Functions in Path and Relay Selection

- **Probing:**
- Sense complete network or local state
- **Inference Logic**
- Local operation for path and relay selection
- **Recovery**

–For path recovery or relay recovery

Thematic Taxonomy



Evaluation of Routing Approaches

Routing Approach	Design	Overhead	latency	connectivity awareness	Optimal route	Scalability
Real-info-assisted	Complex	High	High	✓	Guaranteed	X
Offline-info-assisted	Relatively simple	Moderate	Moderate	X	Probable	Upwards
Infrastructure-assisted	Relatively simple	Moderate	Moderate	✓	Gradual	Upwards & downwards
Path independent	Simple	Low	Low	X	Opportunistic	Upwards

Parametric Protocol Comparison

Protocol	PS	RMT	PG	RS	FO	IL
CAR (Naumov and Gross, 2007)	Ga	Dyn	Iso	SO (greedy)	Anchor proximity	MA
RBVT-R (Nzouonta *et al.*, 2009)	Ga	Dyn	Iso	RO (backoff)	Transmission quality	Inst
RBVT-P (Nzouonta *et al.*, 2009)	Ga	Dyn	Iso	RO (backoff)	Transmission quality	Inst
MOPR-OLSR (Menouar *et al.*, 2007)	Ga	Dyn	Emb	SO (link budget)	Maximum global link stability	Inst
GeoSVR (Xiang *et al.*, 2013)	Gp	Stat	Iso	SO (link budget)	Restricted forwarding	Prob
ACAR (Yang *et al.*, 2008)	Gp	Stat	Iso	SO (node budget)	Reduced packet error rates	Prob
A-STAR (Seet *et al.*, 2004)	Gp	Stat	Iso	SO (greedy)	Maximum forwarding towards destination	Prob
VADD (Zhao and Cao, 2008)	Gp	Stat	Iso	SO (greedy)	Location first/direction first	Prob
SADV (Ding and Xiao, 2010)	Seg	Dyn	Iso	SO (greedy)	Static anchor proximity	MA
GyTAR (Jerbi *et al.*, 2006)	Seg	Dyn	Iso	SO (greedy)	Static anchor proximity	Inst
LoP (Nicolas *et al.*, 2009)	Seg	Dyn	Iso	SO (greedy)	Static anchor proximity	Inst
PROMPT (Jarupan and Ekici, 2010)	Ga	Dyn	Iso	RO (backoff)	Role based	MA
GPCR (Lochert *et al.*, 2005)	Local	Dyn	Emb	SO (greedy)	Junction proximity	Inst
GPSRj+ (Lee *et al.*, 2007)	Local	Dyn	Emb	SO (greedy)	Junction proximity	Inst
CLWPR (Katsaros *et al.*, 2011)	Local	Dyn	Emb	SO (link budget + node budget)	Transmission quality	Inst
GPSR-L (Rao *et al.*, 2008)	Local	Dyn	Emb	SO (link budget)	Link stability	Inst

PS: probing scope; RMT: route metric type; PG: robing granularity; RS: relay selection; FO: forwarding objective; IL: inference logic. Ga: G-active; Gp: G-passive; Seg: segment. Dyn: dynamic; Stat: static. Iso: isolated; Emb: embedded. SO: sender-oriented; RO: receiver-oriented. MA: moving average; Inst: instantaneous; Prob: probabilistic

Competing Protocol Comparison

Protocol	Compared-against	Evaluation metric	Superior	Inferior	Competitive
CAR	Karp and Kung (2000); Naumov *et al.* (2006)	E2ED-12, ROv-12, PDR-12	All	None	No
RBVT	Karp and Kung (2000); Perkins and Royer (1999); Jacquet *et al.* (2001); Lochert *et al.* (2003)	PDR-11, PDR-12, E2ED-12, PS-3, POv-1	All	None	No
MOPR-OLSR	Jacquet *et al.* (2001)	PDR-13, E2ED-13, ROv-13	PDR-13, ROv-13	E2ED-13	No
GPSR-L	Karp and Kung (2000)	PDR-12	All	None	No
GeoSVR	Perkins and Royer (1999); Karp and Kung (2000)	PDR-9, E2ED-7, E2ED-9	All	None	No
ACAR	Karp and Kung (2000); Lochert *et al.* (2003); Naumov and Gross (2007)	PDR-3, E2ED-3, NT-3	All	None	Yes
A-STAR	Karp and Kung (2000); Lochert *et al.* (2003)	PDR-12, E2ED-12	All	None	No
VADD	Self; Karp and Kung (2000) with buffers	PDR-3, PDR-5, PDR-13, E2ED-3, E2ED-5, E2ED-13, ROv-3, PLR-3	All	None	Yes
SADV	Zhao and Cao (2008)	E2ED-8, E2ED-12, ROv-12, POv-12, COv-12, SL-12	All	None	Yes
GyTAR	Ko and Vaidya (1998); Lochert *et al.* (2003)	PDR-3, PDR-12, E2ED-3, E2ED-12, ROv-3, ROv-12	All	None	No
LoP	Lochert *et al.* (2003)	PDR-7, E2ED-4	All	None	No
PROMPT	Johnson *et al.* (2001); Lee *et al.* (2007); Naumov and Gross (2007); Zhao and Cao (2008)	PDR-2, PDR-(10-12), E2ED-2, E2ED-(10-11), COv-10,	All	None	Yes
GPCR	Karp and Kung (2000)	PDR-7, PS-7	All	None	Yes
GPSRj+	Karp and Kung (2000); Lochert *et al.* (2005)	PDR-12, E2ED-12, PS-12	All	None	Yes
CLWPR	Karp and Kung (2000)	PDR-6, PDR-9, E2ED-6, E2ED-9	All	None	No
GPSR-L	Karp and Kung (2000)	PDR-12, PDR-14, PLR-12	All	None	No

Conclusions as Identified Gaps

- **Beacon transmission optimization**
  - Implications of beacon optimization on unicast path accuracy in VANETs
- **Inconclusive protocol evaluation due to lack of realistic evaluation metrics**
  - Hierarchical location service overheads
  - Pruning overheads
- **Incoherent protocol design**
  - Cross-layer interactions for auxiliary information