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Analysis of Buffer Management Policies for Opportunistic Networks

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Outline

Outline

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Motivation

- Mobile Web not always available
  - Outside of cities
  - Third World countries
  - Even in cities, in case of congestion
- Mobile Web is centralized
  - Single point of failure
  - Missing privacy
  - Expensive infrastructure => end-users pay

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Possible Solution

- Mobile devices communicate with each other
  - WiFi, Bluetooth, IR, NFC, etc.
  - Range and bandwidth determined by interface type
  - Independent of Mobile Web
- Message delivery
  - Hop-by-hop routing
  - Indeterministic, churn, overhead
  - More anonymous than Mobile Web

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Challenges

- Routing Protocol
  - Network topology constantly changing
  - Origin and destination might be isolated
  - Node selection for routing
  - Different routing strategies
    - Epidemic (used for evaluation)
    - PRoPHET
    - etc.
- Buffer Management
  - Queue policy: Buffers messages in send queue
  - Drop policy: Drops messages, if queue exhausted
  - Effect on routing performance ?

Outline

Used Routing Protocol

- Epidemic
  - Flooding
  - Best, in terms of delivery ratio
  - Worst, in terms of overhead
  - Exchange summary vectors with nearby nodes
  - Transmit missing messages and buffer
    - Based on queue policy
  - Drop messages, in case of congestion
    - Based on drop policy
  - Routing performance inherently based on Buffer Management
    - Therefore, used by this study

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Other Routing Protocols

- PRoPHET
  - Probability-based
  - Overrides queue policy
- First Contact
  - Node-to-node routing
- Direct Delivery
  - Only deliver to destination directly
- etc.

Buffer Management Policy

- {Queue, Drop} Policy == Sorting order
- Popular policies
  - FIFO - Arrival-time (ascending)
  - LIFO - Arrival-time (descending)
- Further policies used
  - Random
  - Replications (ascending / descending)
  - Relayed-nodes (ascending / descending)
  - Time-to-live (ascending / descending)
  - Message-size (ascending / descending)
- 11 sorting orders per policy
  - 121 different combinations

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Simulation Setup

- Opportunistic Network Environment (ONE) simulator
- Supports only two queue policies
  - Random, FIFO
- Supports only one drop policy
  - FIFO
- Inherently single-threaded
- Contribution
  - All policies implemented
  - Parallelized by running multiple instances

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Methodology

- Multiple scenarios and metrics
  - Each scenario extends base scenario
  - 121 runs per simulated scenario
- Four scenarios
  - Simulated
    - Medium Traffic
    - Frequent and Medium Traffic
    - Frequent, Medium and Demanding Traffic
  - Computed
    - Composite scenario evaluation
- Four metrics
  - Measured
    - Delivery Ratio
    - Overhead Factor
    - Average Delay
  - Computed
    - Composite

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Base Scenario

Parameter	Value
Simulation time	12 hours
Total Number of Nodes	126
Total Number of Node Groups	6
Routing Protocol	Epidemic
Buffer Management Policies	$11 * 11 = 121$
2x Pedestrian Group [Count; Speed]	40; 0.5-1.5 m/s
1x Car Group [Count; Speed]	40; 2.7-13.9 m/s
3x Tram Group [Count; Speed]	2; 7-10 m/s
Movement Model 1 (M1)	Shortest Path Map based Movement
Movement Model 2 (M2)	Map Route Movement
Movement Model Groups [M1; M2]	3; 3
Movement Model Buffers [M1; M2]	5 MB; 50 MB
Interface types	Low-Speed, High-Speed
Low-Speed [Range; Bandwidth]	10 m; 250 KB/s
High-Speed [Range; Bandwidth]	1 km; 10 MB/s
Groups using Low-Speed	All
Groups using High-Speed	1x Tram Group

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Scenarios

Parameter	Value
Message Generators	1
Message Generator 1 [Interval; Size]	25-35 s; 0.5-1 MB

Tabelle: Scenario 1

Parameter	Value
Message Generators	2
Message Generator 1 [Interval; Size]	1-5 s; 0.5-2 KB
Message Generator 2 [Interval; Size]	25-35 s; 64-512 KB

Tabelle: Scenario 2

Parameter	Value
Message Generators	3
Message Generator 1 [Interval; Size]	1-5 s; 0.5-2 KB
Message Generator 2 [Interval; Size]	25-35 s; 64-512 KB
Message Generator 3 [Interval; Size]	60-120 s; 1-5 MB

Tabelle: Scenario 3

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Scenario 1 - Delivery Ratio

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Delivery Ratio (percentage, more is better)										
Queue Policy	X	Random	21.9	25.2	15.1	8.8	39.4	11.4	16.2	23.9	38.3	11.2	10.1
	Ascending	Arrival-time	18.6	25.1	14.2	8.8	38.7	10.3	14.6	21.0	37.5	10.3	10.3
		Replications	25.0	24.7	15.3	8.8	39.9	11.3	15.9	23.3	39.7	9.4	10.5
		Relayed-nodes	30.4	36.8	22.7	10.2	**40.9**	10.6	17.5	26.7	39.1	11.1	10.3
		Time-to-live	18.3	19.1	12.4	9.0	38.2	9.5	16.1	23.8	35.5	10.3	10.9
		Message-size	17.0	18.9	11.6	7.3	33.0	12.0	14.6	23.0	38.7	8.8	9.7
	Descending	Arrival-time	23.2	24.1	15.6	8.5	38.1	11.8	15.9	24.5	40.6	9.4	10.3
		Replications	18.1	20.4	14.7	8.5	35.5	10.2	15.5	21.6	36.2	9.8	10.3
		Relayed-nodes	15.9	17.5	11.8	8.6	32.1	9.6	14.2	23.0	37.4	9.8	10.7
		Time-to-live	30.4	34.0	18.9	9.1	38.0	11.4	16.1	25.5	40.1	9.8	10.1
		Message-size	17.8	20.2	14.2	9.0	31.6	10.3	17.9	25.6	36.1	9.9	11.8

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Scenario 1 - Overhead Factor

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Overhead Factor (transmissions per message, less is better)										
Queue Policy	X	Random	115.6	84.0	145.1	233.3	290.9	127.9	147.9	167.1	242.2	129.6	148.2
	Ascending	Arrival-time	116.6	81.2	144.8	203.0	227.1	134.1	139.8	112.9	161.6	125.8	147.7
		Replications	117.9	89.3	153.6	245.1	329.5	173.4	188.2	148.3	258.5	136.4	140.5
		Relayed-nodes	92.0	**53.5**	123.9	191.6	227.7	193.0	137.7	216.8	273.9	112.7	139.4
		Time-to-live	102.2	91.2	166.2	178.1	212.1	100.0	126.1	88.5	157.9	113.7	138.0
		Message-size	167.4	134.4	239.7	320.3	410.6	501.3	190.6	152.8	293.2	161.4	153.0
	Descending	Arrival-time	136.3	93.7	159.2	252.1	346.4	104.9	156.4	178.4	288.6	139.6	143.9
		Replications	124.0	95.7	140.3	217.5	258.4	105.3	131.1	156.3	149.0	131.0	146.0
		Relayed-nodes	122.5	110.2	183.3	199.4	295.0	97.8	154.0	92.6	172.0	122.6	144.6
		Time-to-live	104.8	62.7	145.0	201.8	350.2	178.0	201.0	284.6	313.4	133.7	143.9
		Message-size	73.4	59.8	105.2	137.2	246.3	91.6	86.1	72.3	137.2	97.9	248.6

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Scenario 1 - Average Delay

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Average Delay (minutes, less is better)										
Queue Policy	X	Random	83.5	78.4	98.3	78.0	58.4	83.7	101.9	79.5	110.1	97.2	75.2
	Ascending	Arrival-time	97.2	92.2	96.6	78.1	67.9	96.8	101.2	95.8	125.4	101.0	75.7
		Replications	68.2	65.4	97.8	67.6	47.6	76.6	94.1	60.9	101.0	81.0	62.2
		Relayed-nodes	72.9	59.4	106.8	71.2	52.7	75.8	94.0	69.4	114.1	93.2	62.0
		Time-to-live	97.6	93.0	96.6	85.5	84.6	92.7	114.1	100.4	124.4	101.9	76.4
		Message-size	78.1	72.2	91.3	71.5	56.0	75.1	103.6	78.2	110.3	79.2	68.8
	Descending	Arrival-time	71.2	55.8	98.3	74.2	45.3	74.8	98.6	64.1	98.0	78.7	61.8
		Replications	97.4	81.8	102.6	82.8	66.1	86.5	107.3	92.8	120.9	96.8	75.8
		Relayed-nodes	83.3	86.4	101.1	83.7	67.7	92.4	103.9	95.7	117.9	85.4	76.0
		Time-to-live	51.6	48.0	90.8	61.4	**40.4**	72.2	90.5	60.8	96.9	71.7	61.8
		Message-size	86.4	73.8	104.5	77.2	61.8	84.2	111.6	87.4	113.7	92.1	74.6

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Scenario 1 - Composite

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Composite (percentage, more is better)										
Queue Policy	X	Random	59.7	67.3	44.9	40.0	73.8	48.3	44.4	59.4	56.0	42.7	48.8
	Ascending	Arrival-time	50.9	61.9	44.7	42.3	74.1	41.5	43.7	54.1	55.2	40.5	48.8
		Replications	68.5	71.5	44.7	43.3	75.6	47.6	44.2	67.5	59.8	46.7	54.8
		Relayed-nodes	73.9	88.5	50.7	47.2	82.2	45.7	49.5	62.4	52.9	45.4	54.8
		Time-to-live	51.6	55.0	41.4	41.4	68.2	44.9	41.1	56.9	53.9	41.1	49.9
		Message-size	53.0	59.7	37.2	34.6	59.5	24.4	39.0	60.0	52.5	45.0	50.6
	Descending	Arrival-time	64.2	74.3	44.4	39.9	73.5	53.9	44.8	65.2	59.6	47.3	54.5
		Replications	49.8	60.3	43.2	39.1	69.3	47.6	42.8	52.7	56.7	41.3	48.9
		Relayed-nodes	53.2	54.5	37.6	40.2	62.6	45.3	41.1	57.7	57.3	46.4	49.3
		Time-to-live	81.4	**89.4**	51.6	49.2	75.0	49.0	44.8	59.5	57.6	51.0	54.4
		Message-size	57.6	65.9	44.6	47.7	68.0	49.6	46.9	65.0	60.2	45.7	43.3

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Scenario 3 - Delivery Ratio

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Delivery Ratio (percentage, more is better)										
Queue Policy	X	Random	55.2	63.5	44.5	33.7	76.3	26.9	47.3	64.1	72.5	38.1	77.3
	Ascending	Arrival-time	41.6	53.0	32.7	23.0	70.5	19.8	35.0	52.2	61.9	27.6	73.2
		Replications	69.3	73.9	59.1	47.3	81.9	33.9	60.3	75.6	81.8	46.5	83.3
		Relayed-nodes	68.7	77.8	60.5	53.6	79.2	33.5	55.1	76.6	74.9	46.0	85.0
		Time-to-live	41.5	46.8	30.2	22.5	61.2	21.0	36.0	58.0	58.6	29.1	71.7
		Message-size	64.0	70.9	62.2	60.8	74.4	43.0	57.9	69.2	71.4	55.4	75.3
	Descending	Arrival-time	63.8	66.9	55.5	42.3	72.1	32.9	57.1	68.3	75.5	43.0	79.2
		Replications	41.7	46.2	31.9	23.0	57.0	19.6	35.7	53.2	60.1	27.7	67.1
		Relayed-nodes	40.3	45.4	30.4	26.8	57.4	18.5	36.8	57.4	60.8	24.4	71.9
		Time-to-live	72.1	77.2	65.1	49.9	76.4	40.3	61.9	76.4	79.8	53.5	**86.0**
		Message-size	29.3	34.0	22.4	20.7	45.2	20.3	27.0	42.5	49.5	21.2	67.3

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Scenario 3 - Overhead Factor

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Overhead Factor (transmissions per message, less is better)										
Queue Policy	X	Random	94.2	83.1	113.5	141.4	65.2	87.5	104.6	76.8	67.7	123.0	74.3
	Ascending	Arrival-time	104.3	85.0	114.6	160.3	59.2	69.5	95.7	87.6	72.1	130.5	69.8
		Replications	82.1	75.7	93.4	115.1	66.5	98.3	91.5	73.8	64.9	112.9	71.8
		Relayed-nodes	65.5	54.4	80.8	85.9	54.6	67.8	76.0	60.2	60.7	89.9	61.4
		Time-to-live	84.5	77.7	107.3	140.7	77.7	93.0	84.3	67.4	75.0	103.4	62.4
		Message-size	98.6	89.5	101.7	102.8	85.1	122.5	105.7	90.8	88.2	111.8	82.0
	Descending	Arrival-time	84.4	77.6	97.0	122.1	75.7	95.2	93.7	78.9	68.3	114.8	67.0
		Replications	112.6	105.8	134.5	156.3	84.9	80.4	109.3	89.3	77.3	137.1	76.1
		Relayed-nodes	97.1	85.9	118.9	142.4	82.5	138.2	106.0	74.4	82.3	168.0	61.4
		Time-to-live	67.8	57.2	77.0	100.1	60.9	86.4	78.0	64.9	59.5	96.1	55.8
		Message-size	23.6	23.0	31.9	31.5	24.5	29.2	35.0	**20.4**	25.7	45.0	33.4

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Scenario 3 - Average Delay

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Average Delay (minutes, less is better)										
Queue Policy	X	Random	63.9	62.1	63.7	50.5	55.2	46.9	66.2	67.6	68.0	54.9	71.9
	Ascending	Arrival-time	68.6	68.7	65.8	50.7	62.7	51.7	70.6	72.0	86.2	55.9	90.1
		Replications	47.4	46.3	47.9	39.6	42.1	37.4	51.0	50.8	49.5	41.6	46.8
		Relayed-nodes	39.0	35.0	54.0	39.7	37.5	33.3	48.2	39.6	57.6	41.6	42.6
		Time-to-live	68.9	65.7	58.5	54.3	86.3	54.1	75.0	86.0	96.9	55.5	98.9
		Message-size	53.7	52.7	47.6	45.4	54.9	48.8	53.0	59.0	61.9	47.9	49.7
	Descending	Arrival-time	37.3	33.8	40.5	33.5	33.6	32.0	46.6	43.5	46.2	37.5	42.5
		Replications	65.8	59.7	63.9	51.7	59.4	49.0	70.5	74.9	84.5	54.6	85.2
		Relayed-nodes	63.9	61.1	56.8	50.6	68.7	51.7	66.8	80.7	86.2	52.2	87.8
		Time-to-live	28.1	26.1	31.7	28.4	25.7	**24.5**	35.8	33.0	36.5	34.2	30.8
		Message-size	55.5	50.1	52.5	51.9	47.0	44.9	61.1	62.8	68.6	52.0	86.2

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Scenario 3 - Composite

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Composite (percentage, more is better)										
Queue Policy	X	Random	50.5	57.9	40.9	35.2	71.4	45.7	43.2	57.2	63.2	39.6	62.4
	Ascending	Arrival-time	39.4	49.3	33.9	25.6	66.5	44.1	37.1	46.9	48.8	32.2	53.2
		Replications	67.6	71.8	59.8	52.7	79.7	50.9	59.4	71.0	76.7	52.0	77.1
		Relayed-nodes	74.8	83.6	60.5	62.4	83.1	59.4	61.6	79.6	70.6	56.9	82.1
		Time-to-live	43.7	49.3	37.6	28.1	47.2	38.2	38.3	48.0	41.7	39.3	50.1
		Message-size	58.4	64.3	59.6	59.6	66.1	44.8	54.1	60.4	60.8	53.8	69.5
	Descending	Arrival-time	68.8	73.5	60.5	51.4	76.6	53.5	59.3	69.6	74.3	51.6	78.1
		Replications	38.8	45.3	29.9	26.0	55.5	42.7	34.5	45.7	47.5	31.4	50.9
		Relayed-nodes	42.5	48.8	35.8	31.6	52.1	27.9	37.5	48.5	46.0	23.9	55.4
		Time-to-live	80.8	86.6	73.7	62.4	85.6	62.5	70.0	81.4	82.7	62.5	**89.2**
		Message-size	57.4	62.3	53.4	53.0	68.8	56.4	51.1	61.4	61.0	50.2	60.2

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Composite Scenario Evaluation - Delivery Ratio

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Delivery Ratio (percentage, more is better)										
Queue Policy	X	Random	46.2	52.7	35.4	23.9	66.8	20.8	38.2	53.1	64.9	27.7	56.7
	Ascending	Arrival-time	36.2	46.5	30.0	18.0	64.0	17.5	32.6	44.6	59.0	21.8	54.3
		Replications	56.3	59.8	45.2	31.5	70.1	24.8	44.7	60.5	**70.6**	31.4	60.6
		Relayed-nodes	58.1	66.9	50.0	35.6	69.5	24.1	42.9	60.9	65.2	30.2	61.4
		Time-to-live	34.9	38.5	25.2	18.1	57.3	17.0	36.1	50.0	55.6	23.3	52.8
		Message-size	54.4	58.3	49.0	43.4	64.3	30.5	47.4	59.0	65.1	37.3	56.9
	Descending	Arrival-time	51.9	54.5	43.0	29.5	62.6	23.8	44.2	56.6	67.1	28.5	58.1
		Replications	35.7	39.8	28.9	17.8	52.5	17.2	31.9	44.9	55.0	21.4	50.2
		Relayed-nodes	33.4	37.7	24.3	20.7	52.3	15.9	32.8	49.4	56.7	19.6	53.2
		Time-to-live	60.0	64.9	50.0	32.2	66.0	27.6	45.5	60.6	69.4	35.6	61.9
		Message-size	26.7	30.0	21.4	16.0	41.6	17.5	34.7	39.9	49.6	18.6	51.9

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Composite Scenario Evaluation - Overhead Factor

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Overhead Factor (transmissions per message, less is better)										
Queue Policy	X	Random	98.4	80.9	123.3	180.3	139.4	103.4	118.6	105.0	122.4	131.6	98.2
	Ascending	Arrival-time	103.9	81.0	118.1	178.2	114.0	91.8	105.5	92.1	96.0	130.1	93.5
		Replications	93.1	79.0	114.3	167.7	154.0	123.8	126.7	97.5	127.4	127.8	94.8
		Relayed-nodes	75.2	55.0	94.9	131.0	114.2	117.6	99.8	114.0	134.2	113.5	87.8
		Time-to-live	88.7	80.7	121.3	156.8	118.0	93.5	92.5	71.0	97.1	110.0	86.8
		Message-size	116.3	101.4	144.8	176.1	192.0	249.3	129.9	107.9	154.1	135.0	103.2
	Descending	Arrival-time	101.8	82.3	118.4	173.7	165.7	102.7	116.3	110.4	141.1	135.0	92.3
		Replications	113.6	99.3	127.5	181.4	141.1	90.4	111.1	109.1	97.5	137.8	97.3
		Relayed-nodes	104.5	92.9	141.4	166.7	147.5	117.0	113.7	77.7	108.5	157.0	88.8
		Time-to-live	80.1	59.8	101.5	150.4	157.6	120.7	123.9	139.1	144.8	119.2	86.5
		Message-size	38.3	**33.4**	52.9	68.2	100.7	52.2	44.4	35.5	59.6	72.8	108.0

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Composite Scenario Evaluation - Average Delay

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Average Delay (minutes, less is better)										
Queue Policy	X	Random	71.3	68.2	75.4	57.9	58.4	59.2	79.6	72.6	85.7	67.6	72.9
	Ascending	Arrival-time	79.6	78.6	80.5	58.3	72.6	67.2	85.6	81.7	107.2	70.1	86.6
		Replications	54.5	52.5	64.7	47.6	44.3	51.1	65.2	54.8	66.8	54.0	51.3
		Relayed-nodes	50.9	43.4	74.5	50.2	43.6	51.8	65.1	49.6	81.7	58.7	48.7
		Time-to-live	79.6	76.1	72.0	62.3	93.3	66.4	93.5	93.9	110.0	70.1	91.4
		Message-size	63.9	61.3	64.1	53.2	57.8	57.8	70.6	67.6	79.6	57.5	58.0
	Descending	Arrival-time	48.4	41.2	60.9	47.1	37.5	49.4	64.9	51.9	64.6	51.4	48.8
		Replications	77.3	68.4	80.3	60.0	68.2	62.5	86.7	81.9	100.8	68.0	83.3
		Relayed-nodes	71.4	70.9	72.0	61.3	73.6	65.7	84.6	88.4	99.7	62.5	84.2
		Time-to-live	36.0	33.5	52.6	39.8	**30.7**	44.9	55.0	43.0	58.5	46.8	40.8
		Message-size	68.0	61.0	73.9	59.5	55.3	60.2	87.3	75.3	93.1	65.2	82.2

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Composite Scenario Evaluation - Composite

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Composite (percentage, more is better)										
Queue Policy	X	Random	55.4	62.6	43.6	36.3	72.8	46.2	44.6	59.4	62.1	40.1	59.3
	Ascending	Arrival-time	45.6	55.2	39.8	32.3	68.1	43.9	41.5	51.4	52.2	36.2	53.3
		Replications	69.0	73.1	55.2	47.4	79.0	49.2	53.8	71.0	72.6	48.4	70.5
		Relayed-nodes	74.9	85.8	57.4	53.9	83.1	50.8	56.6	73.7	63.2	48.3	73.4
		Time-to-live	47.5	52.0	41.0	34.1	54.6	41.8	42.3	52.8	48.5	40.7	51.7
		Message-size	60.1	65.0	54.0	52.1	65.1	37.6	52.0	62.9	60.4	49.2	64.6
	Descending	Arrival-time	68.1	74.6	55.1	45.8	76.3	50.9	54.4	69.2	70.5	46.7	71.0
		Replications	44.5	52.2	37.2	31.4	59.5	44.6	39.3	49.9	51.8	35.4	51.9
		Relayed-nodes	47.3	51.7	37.1	34.7	56.8	36.5	40.8	53.4	51.9	32.3	54.7
		Time-to-live	81.5	**87.8**	65.5	52.9	82.6	54.1	59.7	73.8	74.4	55.2	77.5
		Message-size	57.6	62.9	50.6	51.1	67.0	53.2	52.8	62.8	60.0	47.6	55.8

Outline

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Conclusion

- Differently sized messages influence each other
- Epidemic routing performance depends on {queue, drop} policy
- Each metrics has other characteristics
  - But: A few policies are preferable on average

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Future Work

- More scenarios
- More metrics
- More routing protocols
- More {queue, drop} policies

Scenario 2 - Delivery Ratio

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			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Delivery Ratio (percentage, more is better)										
Queue Policy	X	Random	61.3	69.4	46.8	29.4	84.6	24.1	51.0	71.2	84.0	33.7	82.7
	Ascending	Arrival-time	48.5	61.3	43.0	22.3	82.7	22.4	48.3	60.7	77.6	27.6	79.4
		Replications	74.6	80.8	61.3	38.3	88.4	29.3	57.8	82.7	**90.2**	38.4	88.1
		Relayed-nodes	75.3	86.1	66.8	43.0	88.5	28.3	55.9	79.5	81.5	33.5	88.9
		Time-to-live	44.9	49.6	33.0	22.7	72.5	20.6	56.2	68.2	72.8	30.4	75.8
		Message-size	82.4	85.2	73.1	62.2	85.6	36.5	69.7	85.0	85.1	47.7	85.6
	Descending	Arrival-time	68.6	72.5	57.8	37.7	77.6	26.6	59.5	77.0	85.3	33.1	84.7
		Replications	47.4	52.9	40.1	21.9	65.0	22.0	44.7	59.8	68.6	26.9	73.4
		Relayed-nodes	44.0	50.2	30.8	26.8	67.3	19.7	47.5	67.7	71.9	24.6	77.0
		Time-to-live	77.5	83.5	66.0	37.6	83.6	31.0	58.6	79.8	88.3	43.4	89.7
		Message-size	32.9	35.8	27.7	18.5	47.9	22.0	59.3	51.6	63.3	24.7	76.6

Scenario 2 - Overhead Factor

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			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Overhead Factor (transmissions per message, less is better)										
Queue Policy	X	Random	85.5	75.7	111.3	166.2	62.2	94.8	103.2	71.2	57.3	142.1	72.2
	Ascending	Arrival-time	90.8	76.8	94.9	171.3	55.7	71.7	81.0	75.7	54.3	134.0	63.1
		Replications	79.3	72.0	96.1	142.8	65.9	99.6	100.3	70.4	58.8	134.1	72.3
		Relayed-nodes	68.2	56.9	79.9	115.4	60.3	91.9	85.6	64.9	67.9	137.8	62.7
		Time-to-live	79.5	73.2	90.6	151.6	64.3	87.5	67.0	57.2	58.6	113.0	60.0
		Message-size	83.1	80.2	93.0	105.2	80.5	124.0	93.3	80.0	81.0	131.7	74.5
	Descending	Arrival-time	84.7	75.6	99.1	146.9	75.0	108.1	98.9	73.9	66.2	150.5	66.1
		Replications	104.3	96.4	107.8	170.4	80.0	85.3	93.0	81.7	66.1	145.4	69.8
		Relayed-nodes	93.8	82.7	121.9	158.2	65.1	114.8	81.2	66.1	71.2	180.4	60.5
		Time-to-live	67.7	59.4	82.5	149.3	61.6	97.8	92.7	67.9	61.5	127.9	59.8
		Message-size	17.9	17.5	21.4	35.9	31.1	35.8	**12.2**	13.8	15.9	75.5	42.2

Scenario 2 - Average Delay

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			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Average Delay (minutes, less is better)										
Queue Policy	X	Random	66.6	64.1	64.3	45.2	61.6	47.0	70.5	70.6	79.1	50.9	71.4
	Ascending	Arrival-time	72.9	75.0	79.1	46.2	87.3	53.0	84.8	77.4	110.0	53.6	94.0
		Replications	47.8	46.0	48.4	35.5	43.1	39.3	50.6	52.7	49.8	39.4	44.8
		Relayed-nodes	40.9	35.8	62.8	39.7	40.6	46.3	53.3	39.8	73.4	41.4	41.4
		Time-to-live	72.4	69.7	60.9	47.0	109.1	52.5	91.3	95.3	108.7	52.9	98.9
		Message-size	59.8	59.1	53.4	42.8	62.7	49.3	55.3	65.6	66.8	45.4	55.6
	Descending	Arrival-time	36.8	33.8	44.0	33.6	33.7	41.3	49.5	48.0	49.5	38.0	42.0
		Replications	68.8	63.8	74.4	45.5	79.0	52.2	82.3	78.1	96.9	52.5	89.1
		Relayed-nodes	67.1	65.2	58.0	49.6	84.4	53.0	83.2	88.9	94.8	49.7	88.6
		Time-to-live	28.3	26.5	35.2	29.6	**26.0**	38.0	38.8	35.2	42.1	34.6	29.8
		Message-size	62.2	59.0	64.8	49.4	57.2	51.5	89.3	75.6	96.9	51.6	85.9

Scenario 2 - Composite

			Drop Policy										
			X	Ascending					Descending				
			Random	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size	Arrival-time	Replications	Relayed-nodes	Time-to-live	Message-size
Metric			Composite (percentage, more is better)										
Queue Policy	X	Random	56.0	62.6	45.0	33.6	73.4	44.6	46.1	61.8	67.1	38.1	66.6
	Ascending	Arrival-time	46.4	54.3	40.6	28.9	63.6	46.0	43.6	53.3	52.5	35.9	57.9
		Replications	70.8	75.9	61.1	46.3	81.7	49.1	57.8	74.4	81.3	46.5	79.6
		Relayed-nodes	76.0	85.3	61.1	52.2	83.9	47.4	58.7	79.1	66.1	42.6	83.3
		Time-to-live	47.2	51.7	44.0	32.7	48.5	42.2	47.4	53.4	49.9	41.6	54.9
		Message-size	68.9	71.0	65.2	61.9	69.8	43.7	62.8	68.4	67.8	48.9	73.7
	Descending	Arrival-time	71.3	76.1	60.6	45.9	78.7	45.4	59.2	72.9	77.7	41.3	80.4
		Replications	44.9	51.0	38.6	29.2	53.8	43.4	40.5	51.4	51.1	33.7	55.7
		Relayed-nodes	46.1	51.9	38.0	32.3	55.7	36.2	43.8	53.9	52.5	26.8	59.4
		Time-to-live	82.2	87.4	71.2	47.0	87.1	50.8	64.3	80.4	82.9	52.0	**88.9**
		Message-size	57.9	60.6	53.8	52.7	64.2	53.5	60.5	62.1	58.7	46.9	64.0