HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

Analysis of Buffer Management Policies for Opportunistic Networks

Salem Sati, Christopher Probst, Kalman Graffi

Department of Computer Science, University of Düsseldorf, Germany

04.08.2016

Outline

Outline

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

Motivation

- Mobile Web not always available
  - Outside of cities
  - Third World countries
  - Even in cities (congestion, buildings, ...)
- Mobile Web is centralized
  - Missing privacy (surveillance)
  - Limited traffic (depends on country)
  - Expensive infrastructure

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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
  - Opportunistic routing
  - Indeterministic, churn, overhead
  - Anonymous

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

Used Routing Protocol

- Epidemic
  - Basically flooding
  - High delivery probability + overhead
  - Exchange summary vectors with nearby nodes
  - Transmit missing messages and buffer
    - Based on queue policy
  - Drop messages if congested
    - Based on drop policy
  - Routing performance inherently based on Buffer Management
    - Good fit for first study

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

Other Routing Protocols

- PRoPHET
  - Probability-based
  - Overrides queue policy
    - Fallback if probabilities are equal
- 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
  - 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

Outline

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

Simulation Setup

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

Outline

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

Outline

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

Future Work

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

Scenario 2 - Delivery Ratio

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

			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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

			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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

			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

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

			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