BORDER MONITORING WITH WIRELESS SENSOR NETWORKS

ELE 402 - Special Topics in Automation Systems

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SUMMARY

- Problem definition
- Simulatin environment
- Metrics
- Simulation setup
- Simulation results

- Problem definition

PROBLEM DEFINITION

Evaluate four different routing protocols (DSR, AODV, DSDV and TORA) in the application of border surveillance system in order to meet performance metrics regarding energy consumption, packet delivery ratio, end-to-end delay and throughput.

Border Monitoring Characteristics:

- Long distances and relative narrow range of area to be monitored;
- Usually it demands high cost or even infeasible for installation of infrastructure;
- Demands discretion in order to avoid being located and destroyed by the invader;

WSNs Suitability

- Easy field implementation;
- Centralized/Decentralized control;
- Static/Mobile sink;
- Auto-configurable;

MOTIVATION AND RELEVANCE

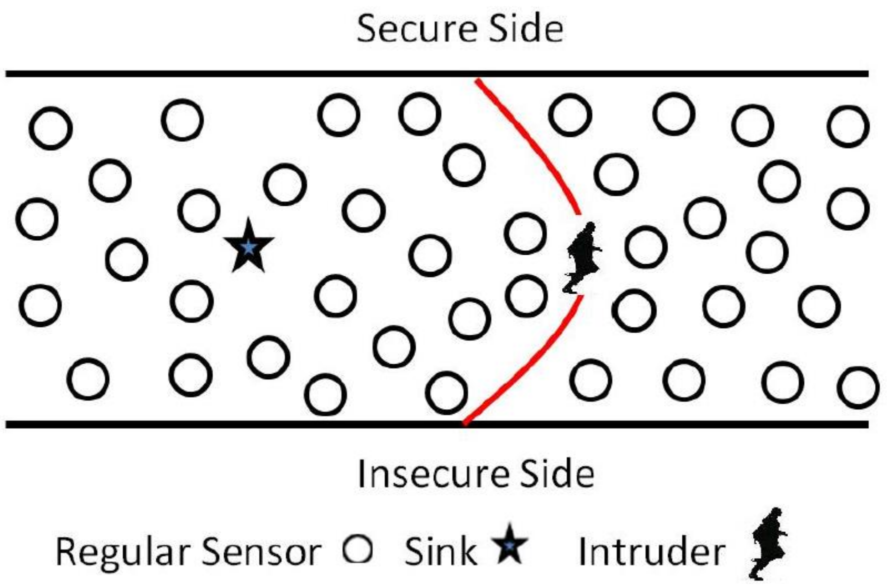
Border surveillance characteristics:

- Border extensions to be monitored is about 17,000 km;
- Only about 4% of our border is monitored;
- Hostile and uninhabited topography;
- Sparse intrusion events occurrence;
- Long time interval between events;
- Cost constraint;

- Simulatin environment

SIMULATION ENVIRONMENT

NETWORK SIMULATOR (NS-2)



- Environment Definition and Configuration
  - Narrow and long distance area representing a border surveillance scenario [1][2];
  - Simulate the intruder detection via U.S. Naval Research Laboratory extension to NS-2 (nrlsensorsim) [3]:
    - PHENOM broadcast packets through a specific channel;
    - Adjust the sensing sensitivity of the physical phenomenon by the transmission range of the broadcasted packets;
    - Do not contributes with network overhead once PHENOM protocol works independently from the WSN protocol.

- Metrics

METRICS TO EVALUATE THE PROTOCOLS

NETWORK METRICS

In order to quantitatively compare the options, four metrics have been considered based on [1], [2] and [4]:

End-to-End delay	Packet delivery ration (PDR)
$D = \frac{\sum_{i=1}^{Pt} Delay_i}{Pt}$	$PDR = \frac{\sum_{n=1}^{N_{DP}} n}{\sum_{m=1}^{N_{SP}} m}$
Throughput	**Energy consumption**
$Th = \frac{\sum_{i=1}^{Pt} P_{Si}}{S_t}$	$E_{avr} = \frac{\sum_{i=1}^{Nn} e_i}{Nn}$ $E_{max} = \max_{i=1 \ldots Nn} e_i$

- Simulation setup

SIMULATION SETUP

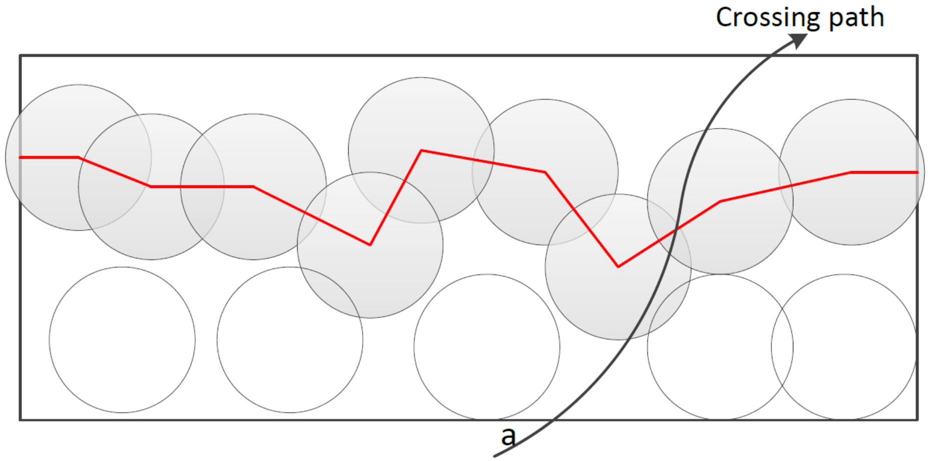
SIMULATION

- Rectangle sensor area (10 km x 500 m);
- Deterministic and random sensor deployment;
- Protocols:
  - Static and mobile sink;
  - On-demand and proactive;
  - DSR – Dinamic Source Routing;
  - DSDV – Destination Sequence Distance Vector;
  - AODV – Ad-hoc On Demand Routing Protocol;
  - TORA – Temporarlly Ordered Routing Algorithm (did not work in NS-2.26 until now);
- Population criterion – node density;

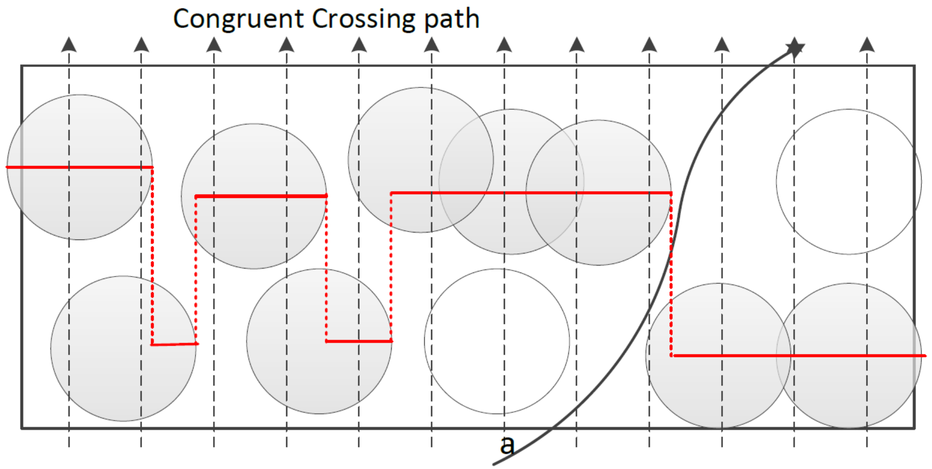
SIMULATION SETUP

CALCULATION OF THE NODE DENSITY [1][7]

- Strong Barrier Coverage



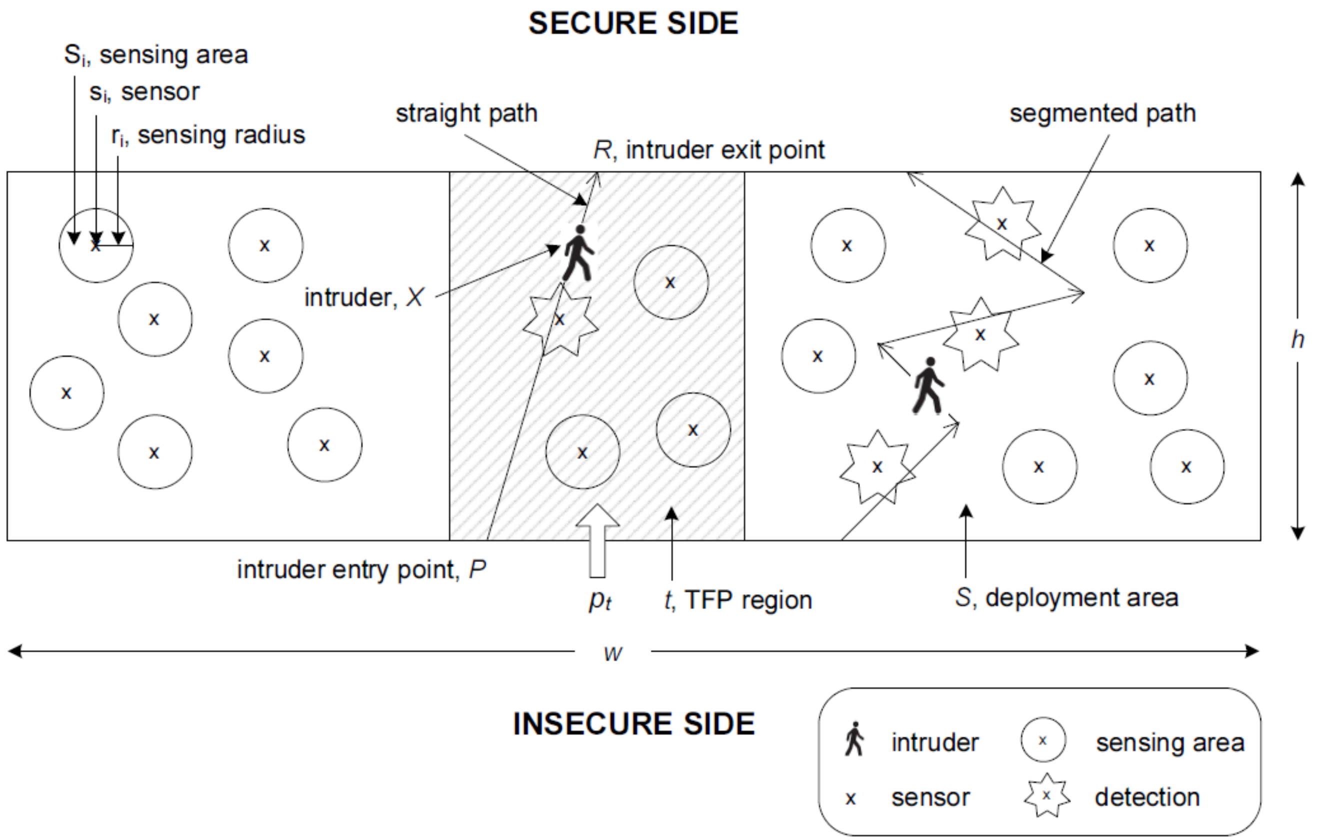
- Weak Barrier Coverage / Orthogonal Detection



SIMULATION SETUP

CALCULATION OF THE NODE DENSITY

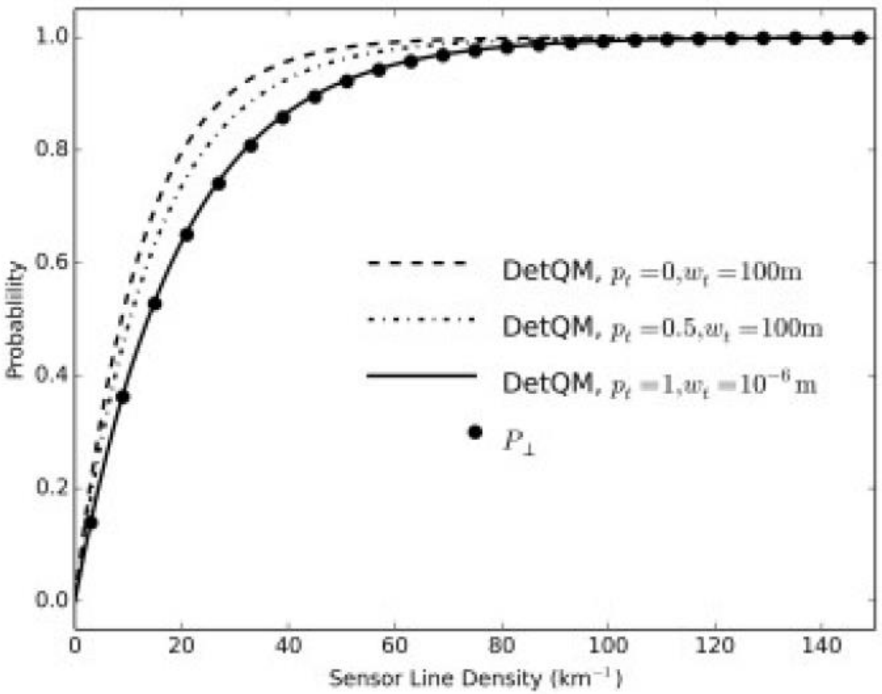
- DetQM [7]

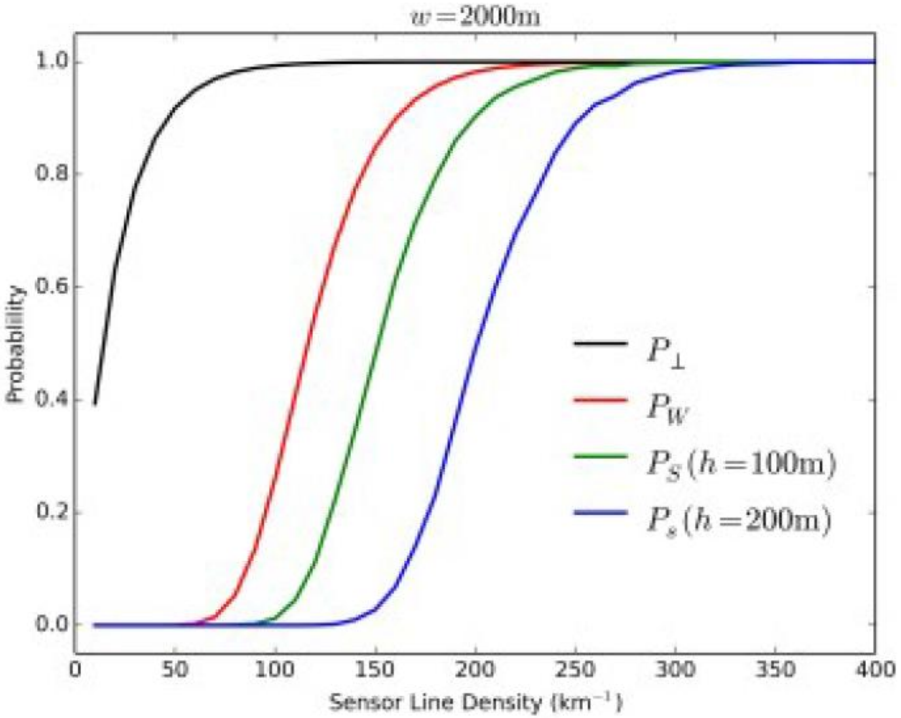


SIMULATION SETUP

CALCULATION OF THE NODE DENSITY

[1] M. Hammoudeh *et al.*, ***"A Wireless Sensor Network Border Monitoring System: Deployment Issues and Routing Protocols"***, in *IEEE Sensors Journal*, vol. 17, no. 8, pp. 2572-2582, 15 April15, 2017. doi: 10.1109/JSEN.2017.2672501





SIMULATION SETUP

CALCULATION OF THE NODE DENSITY [1] [8]

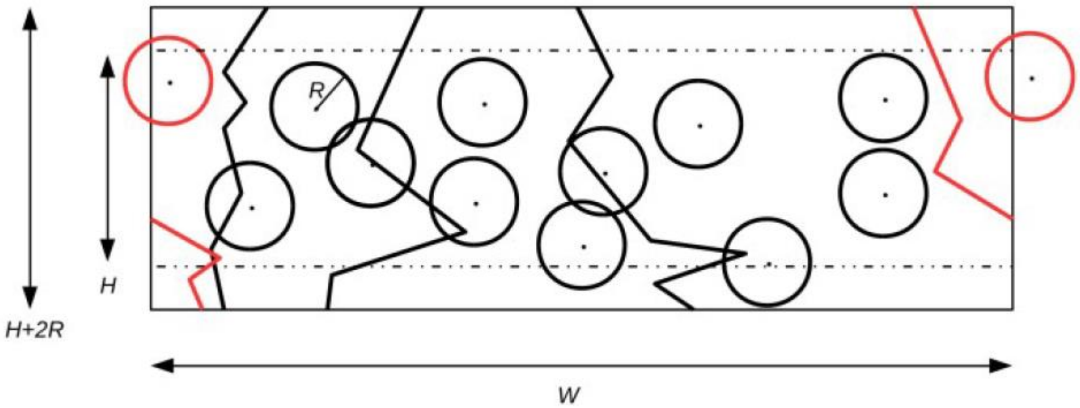
- Radio Communication
  - Probability that a node can communicate with at least one other node is derived from Poisson Distribution

$$P_{radio} = 1 - e^{-\frac{\rho\pi R_{radio}^2}{H}} \qquad P_{\perp} = 1 - e^{-2\rho R_{sensor}}$$

ρ is the node linear density in nodes per meter
R_{radio} is the radio range in meter
R_{sensor} is the sensor range in meter
H is the field height

According to the reference, a typical application ($R_{radio} \approx 2\, R_{sensor}$, $R_{sensor} = 25$ m and H = 100 m

$$P_{radio} > P_{\perp}$$

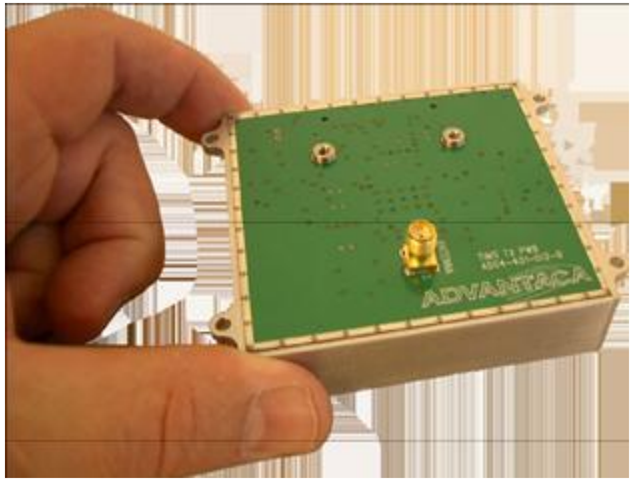


SIMULATION SETUP

SENSOR EXAMPLE

- SEGA-Node TIMS Radar
  - Radar Typical Performance

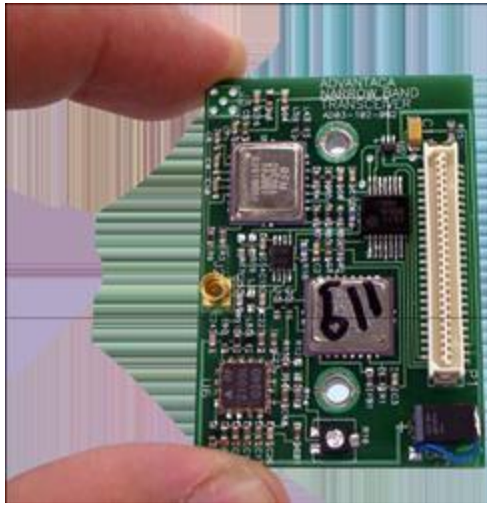
Range	35 M
Frequency	720 MHz
Bandwidth	80 MHz
Tx Power	9 mW
Voltage	3.6 V
Current	5 mA
Temp	-40 to +80 C
Target speed	0.1 to 40 m/s



http://www.sperient.com/ (last access on 2018/12/09)

- SEGA-Node TIMS Radar
  - Radio Typical Performance

Range	1 KM
Frequency	315 Mhz
Bandwidth	400 KHz
Tx Power	2 mW
Voltage	3.0 V
Current	1.5 mA
Temp	-40 to +80 C



- Simulation results

SIMULATION RESULTS

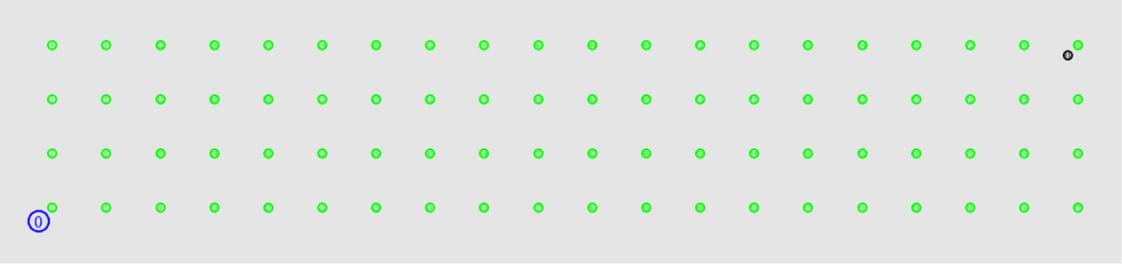
CONFIGURATION

- Equivalent linear sensor density
- Sensor range: 35 m
- Radio range: 250 m
- Number of sensor nodes: 40, 80, 120, 160, 200, 240 and 280
- Simulation time: 500 sec

SIMULATION RESULTS

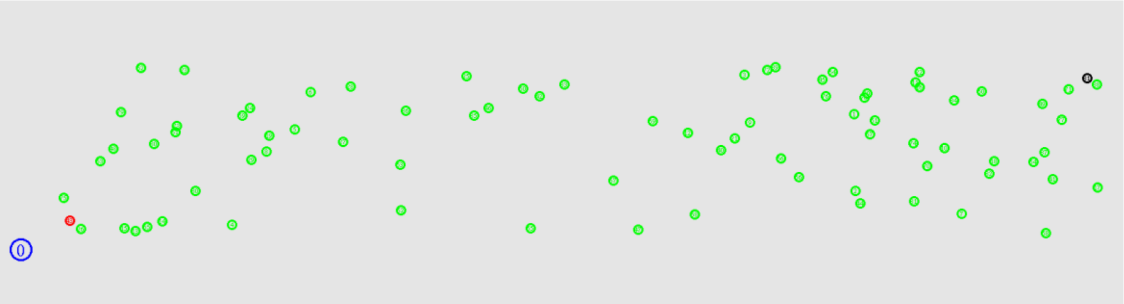
SCENARIOS

Scenario 1



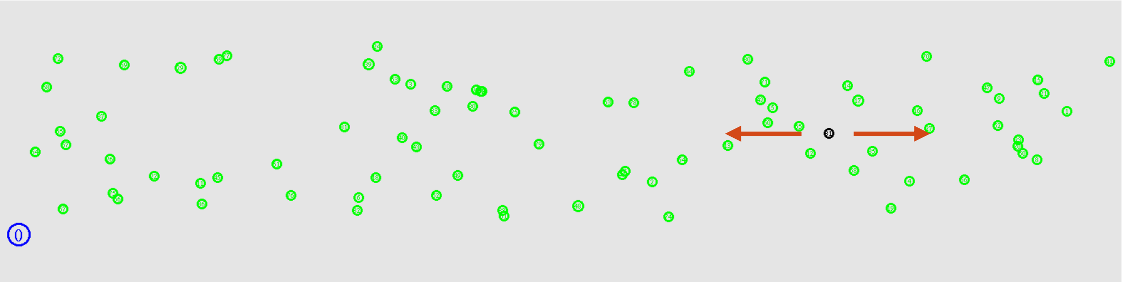
- Deterministic sensor nodes depoloyment;
- Targuet and sink nodes static;

Scenario 2



- Stochastic sensor nodes depoloyment;
- Targuet and sink nodes static;

Scenario 3

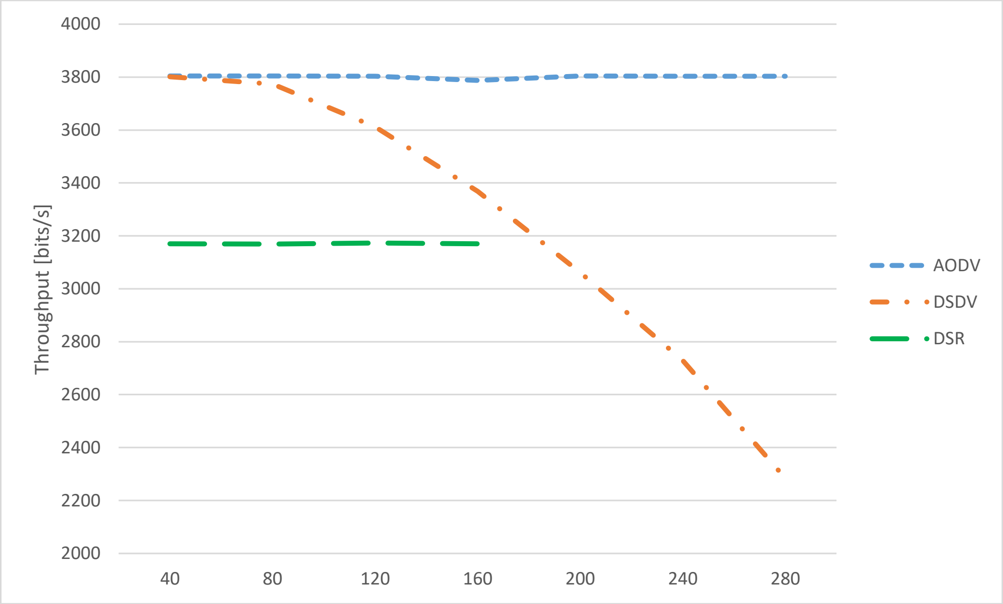


- Stochastic sensor nodes depoloyment;
- Targuet node static;
- Sink node moving along “x” axis;

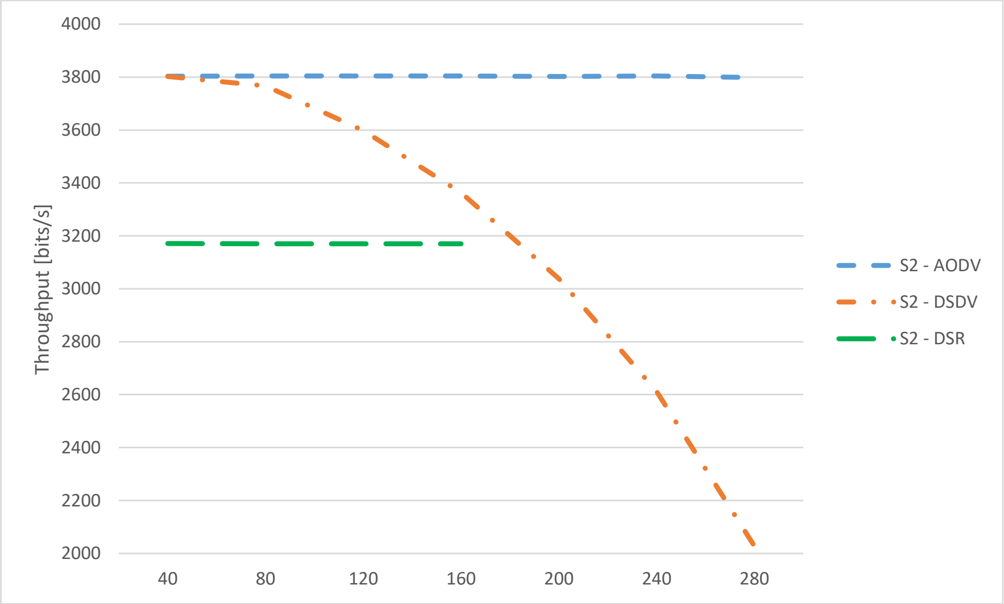
SIMULATION RESULTS

SCENARIOS – COMPARATIVE - THROUGHPUT

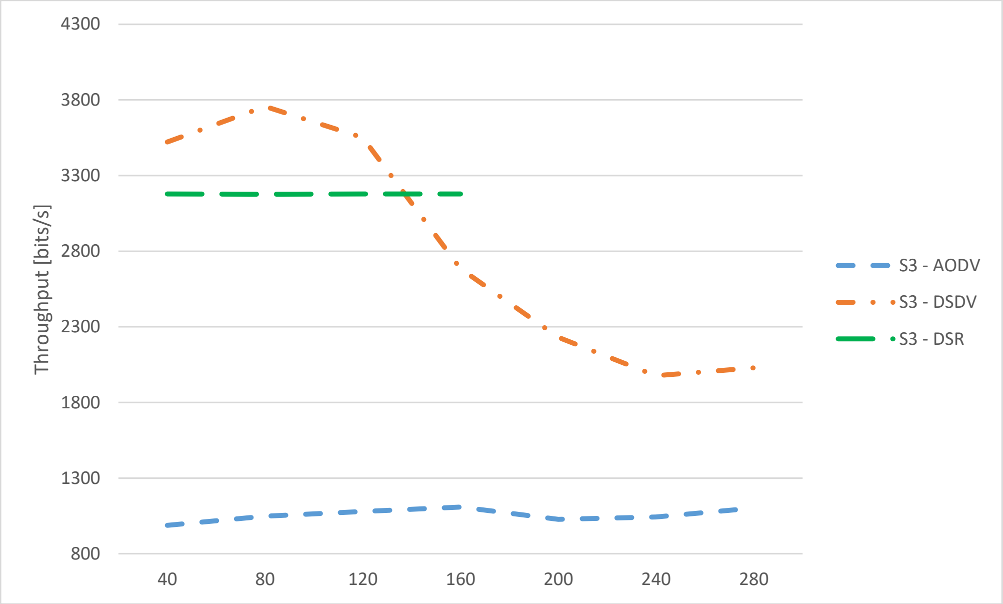
SCENARIO 1



SCENARIO 2



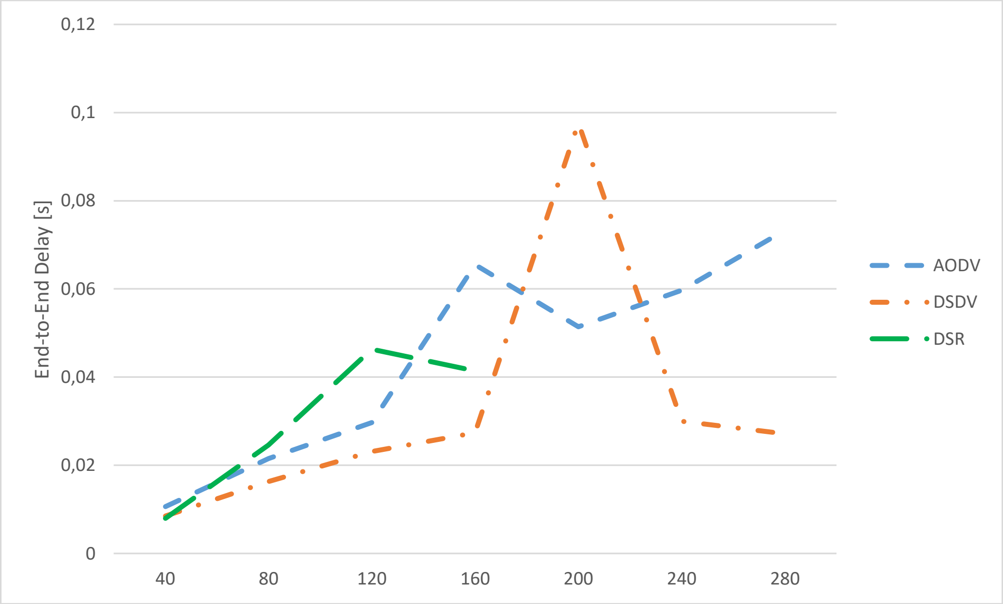
SCENARIO 3



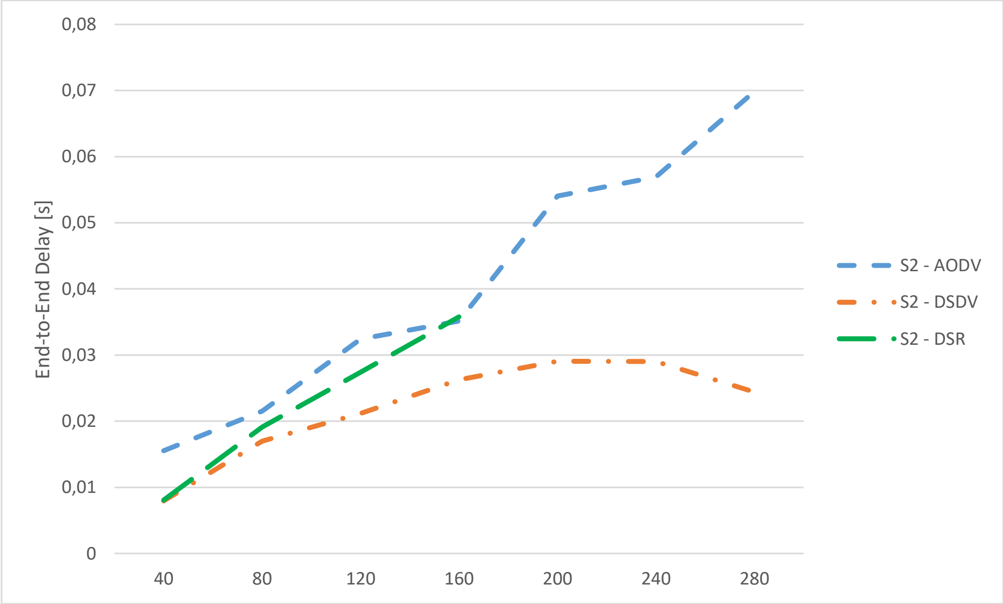
SIMULATION RESULTS

SCENARIOS – COMPARATIVE – END-TO-END DELAY

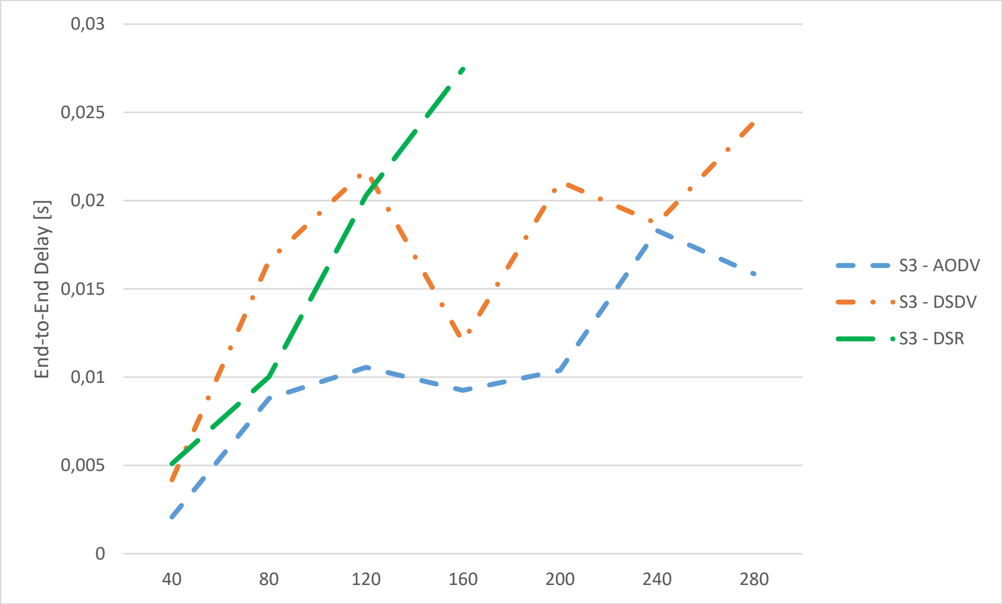
SCENARIO 1



SCENARIO 2



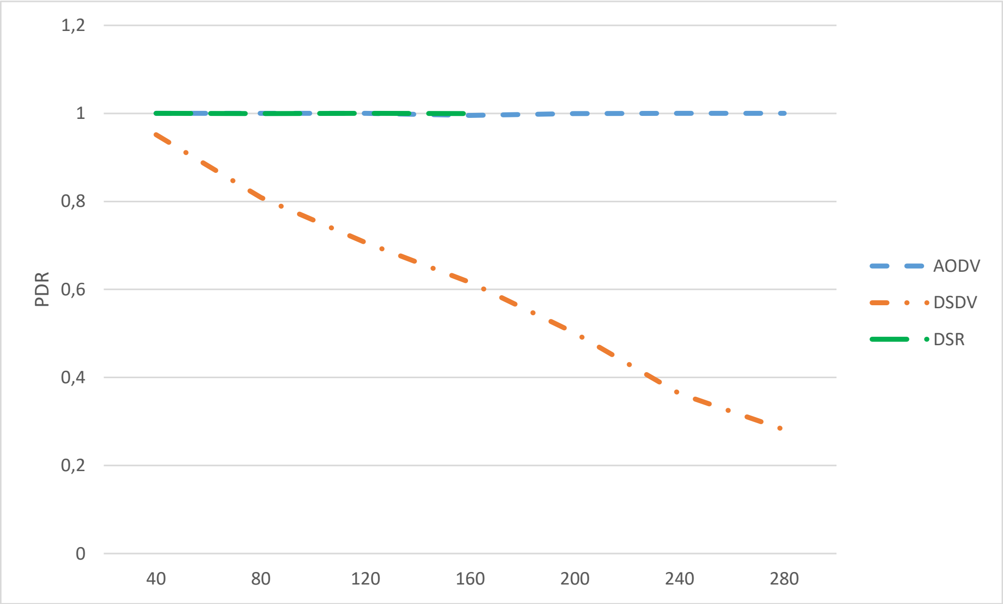
SCENARIO 3



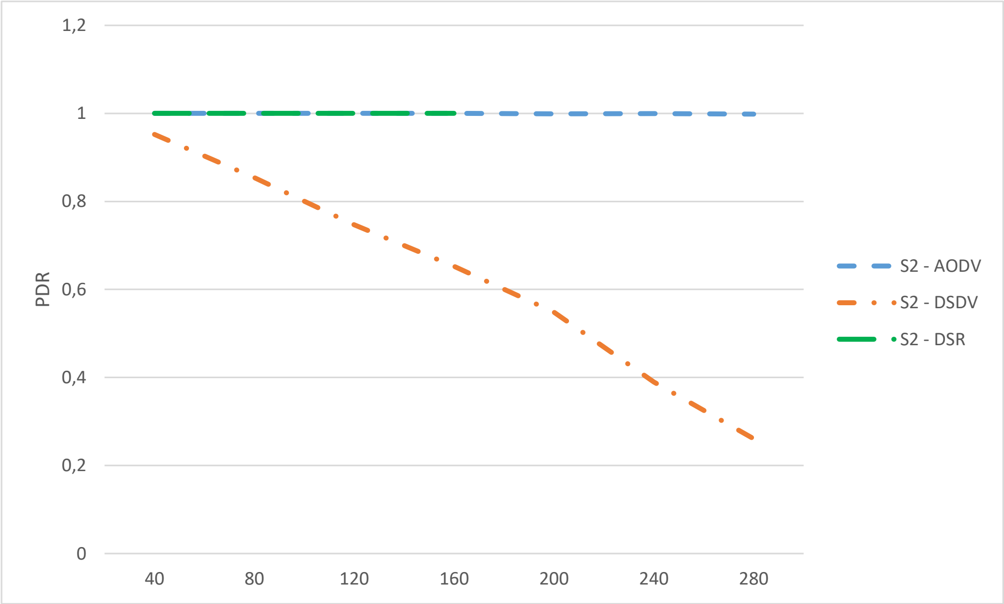
SIMULATION RESULTS

SCENARIOS – COMPARATIVE – PDR

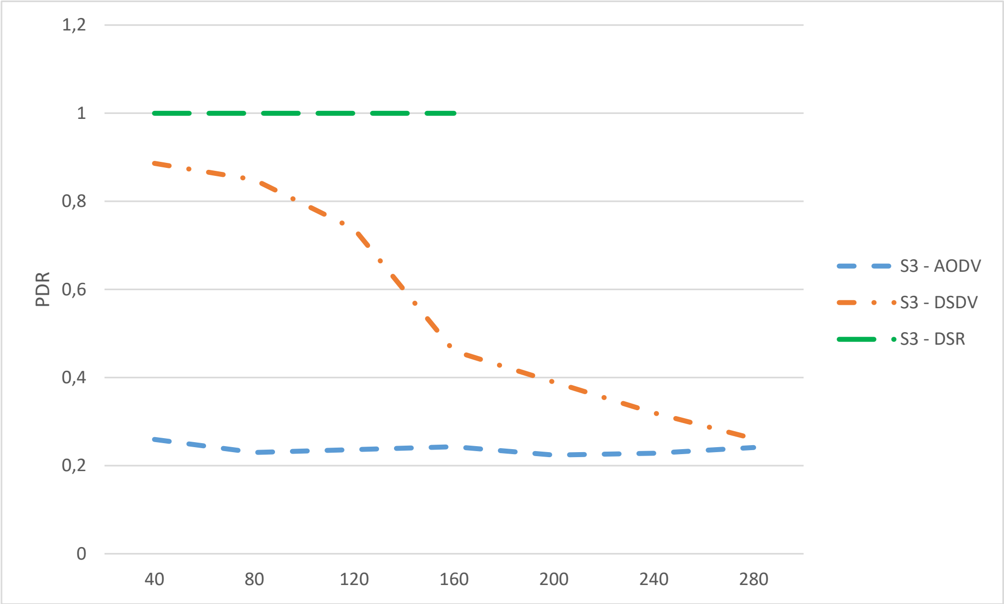
SCENARIO 1



SCENARIO 2



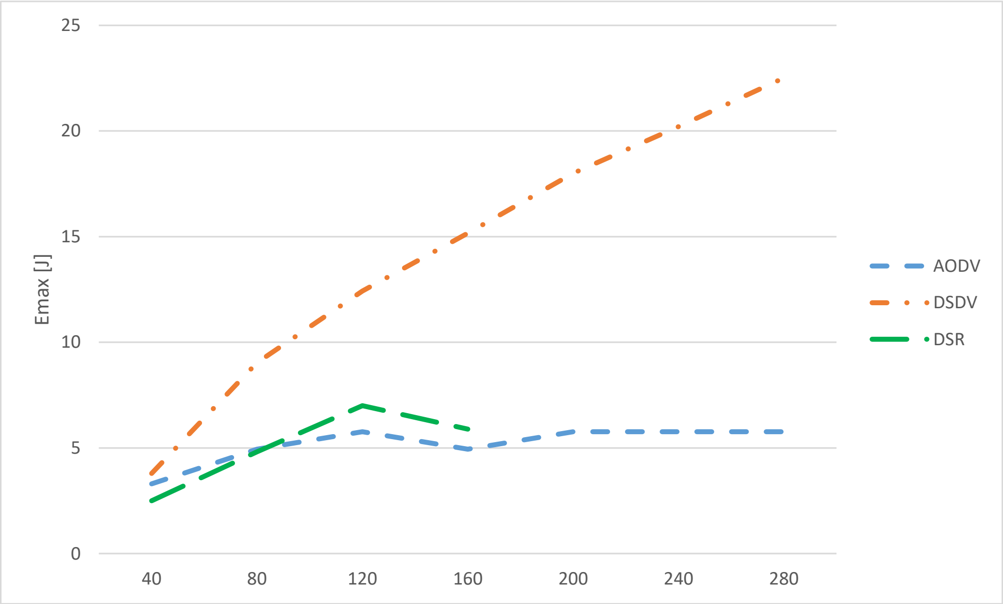
SCENARIO 3



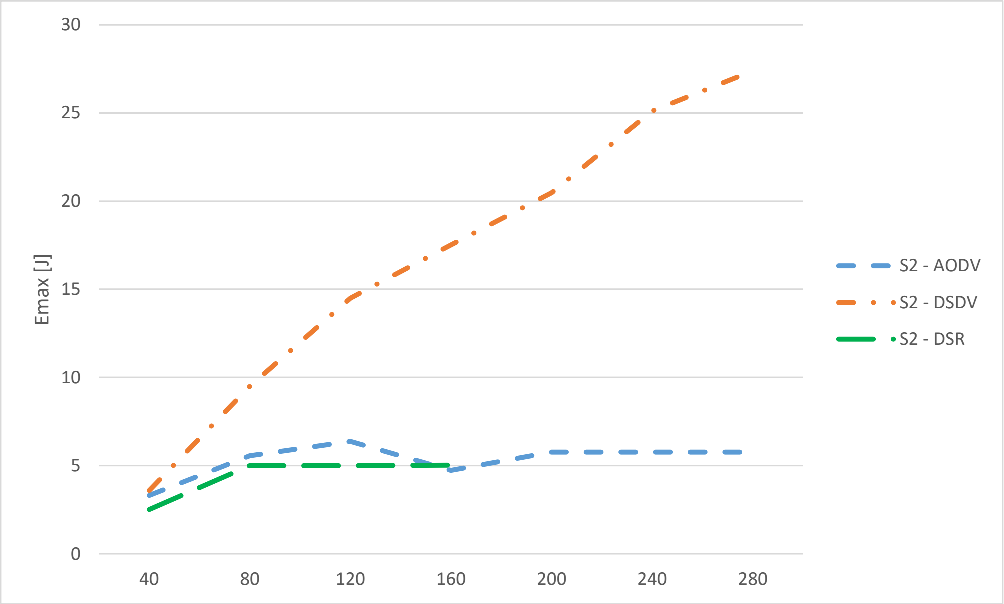
SIMULATION RESULTS

SCENARIOS – COMPARATIVE – Emax

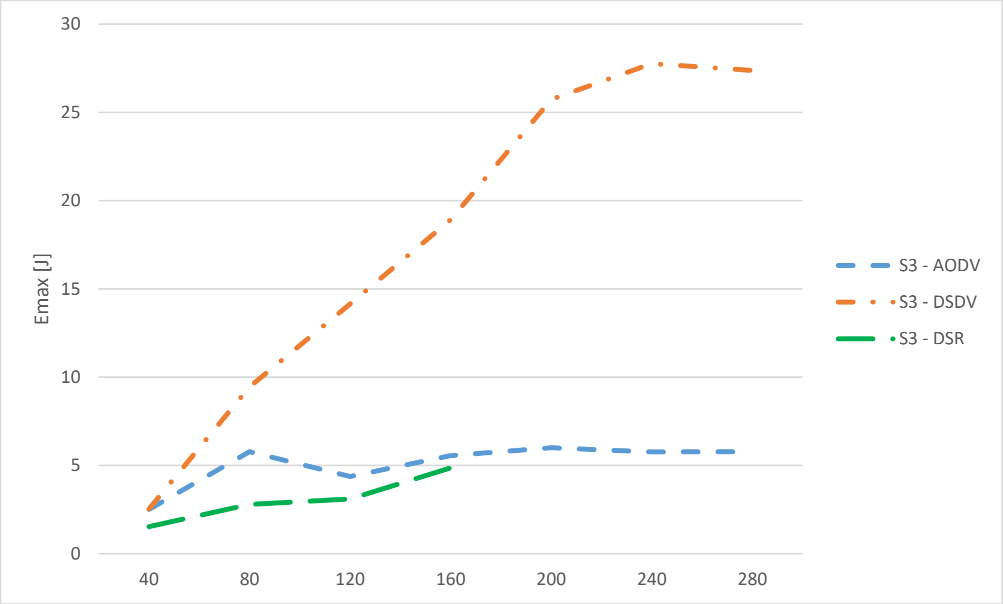
SCENARIO 1



SCENARIO 2



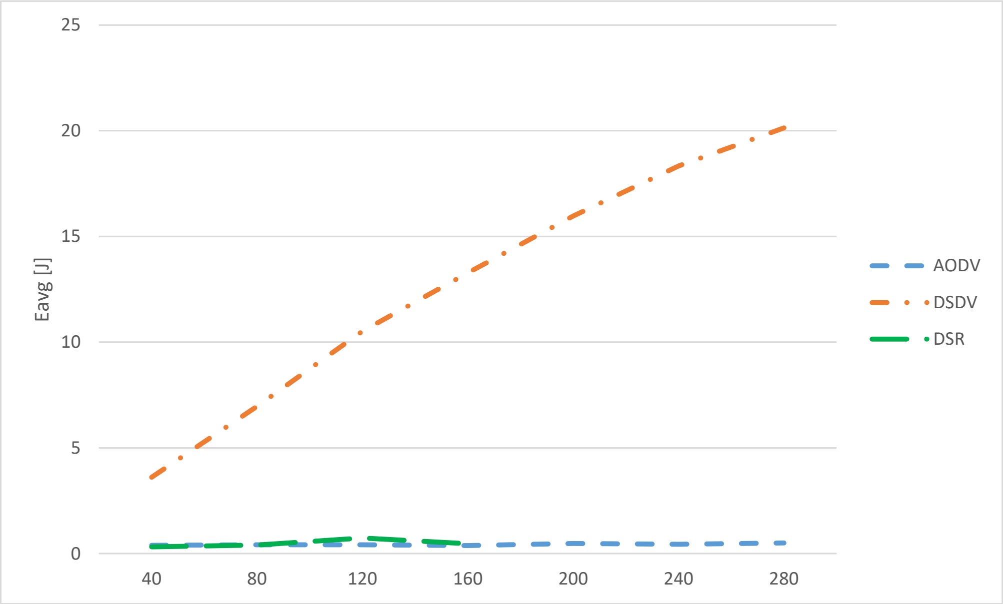
SCENARIO 3



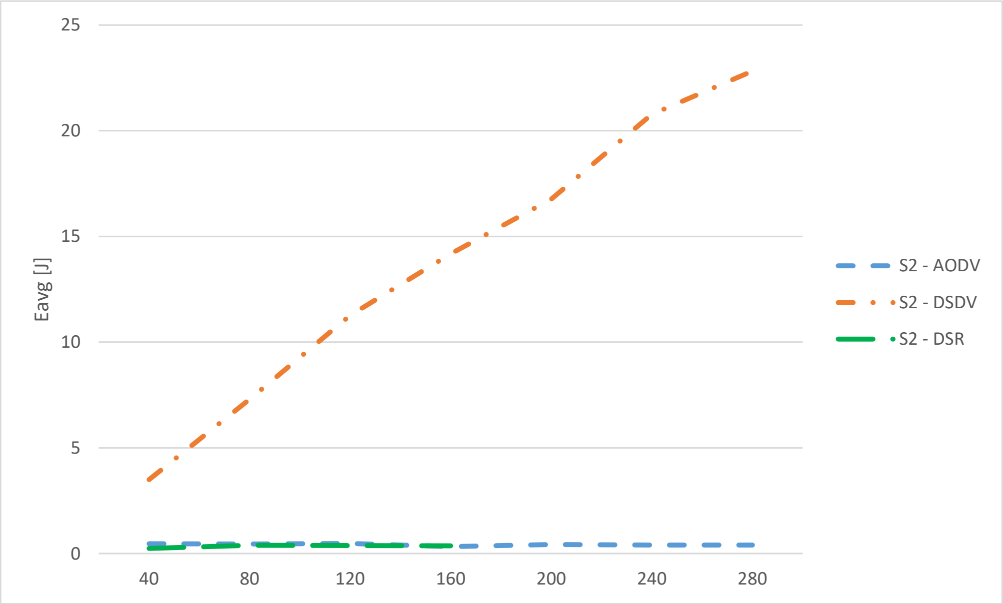
SIMULATION RESULTS

SCENARIOS – COMPARATIVE – Eavg

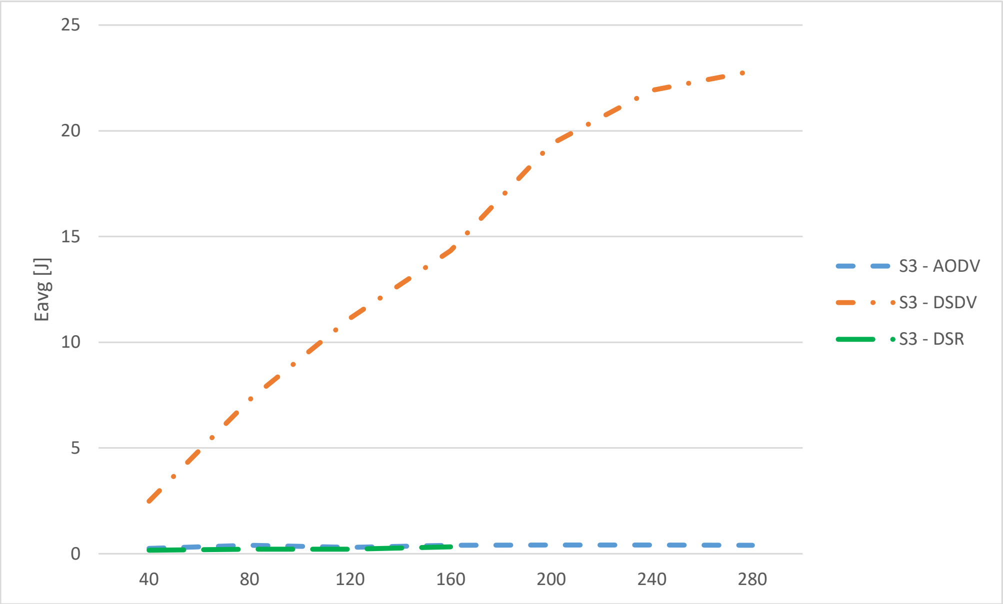
SCENARIO 1



SCENARIO 2



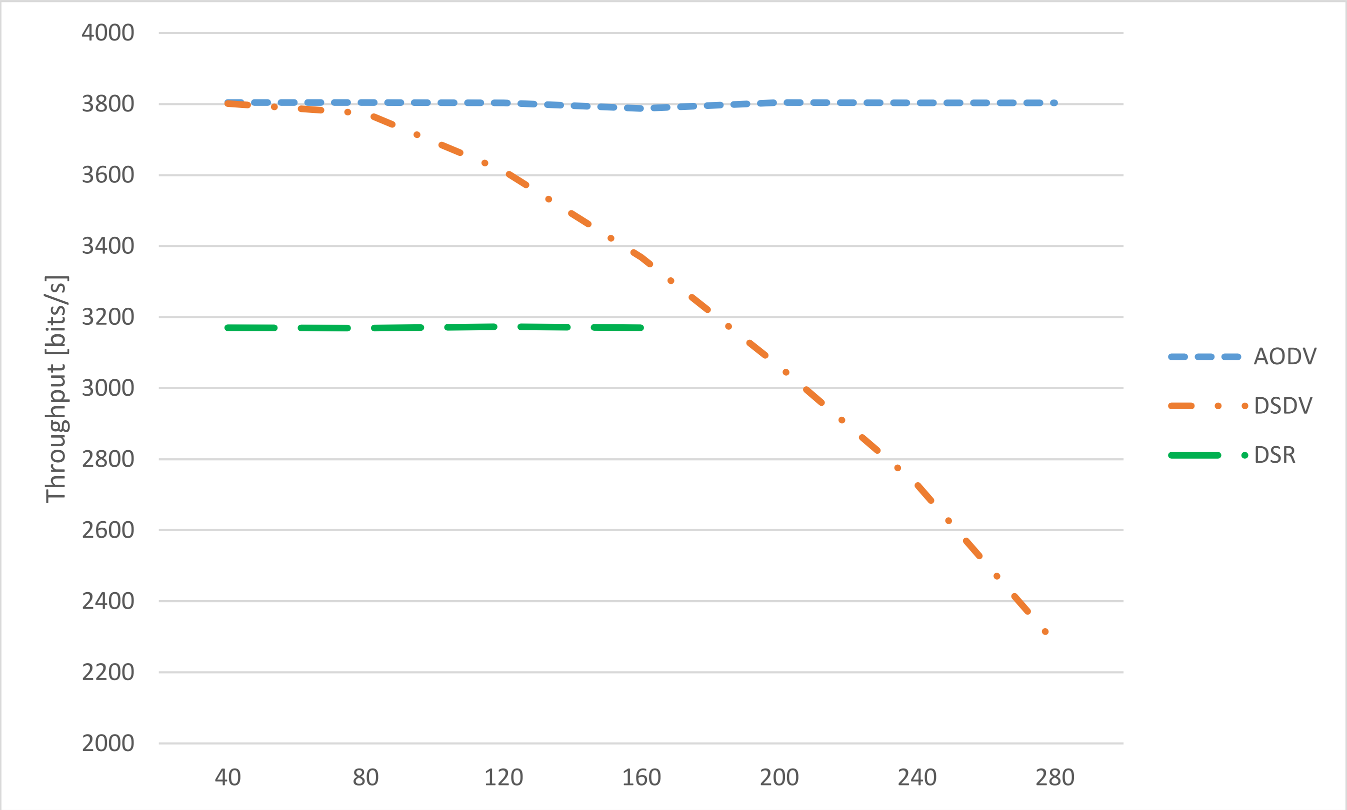
SCENARIO 3



SIMULATION RESULTS

SCENARIO 1

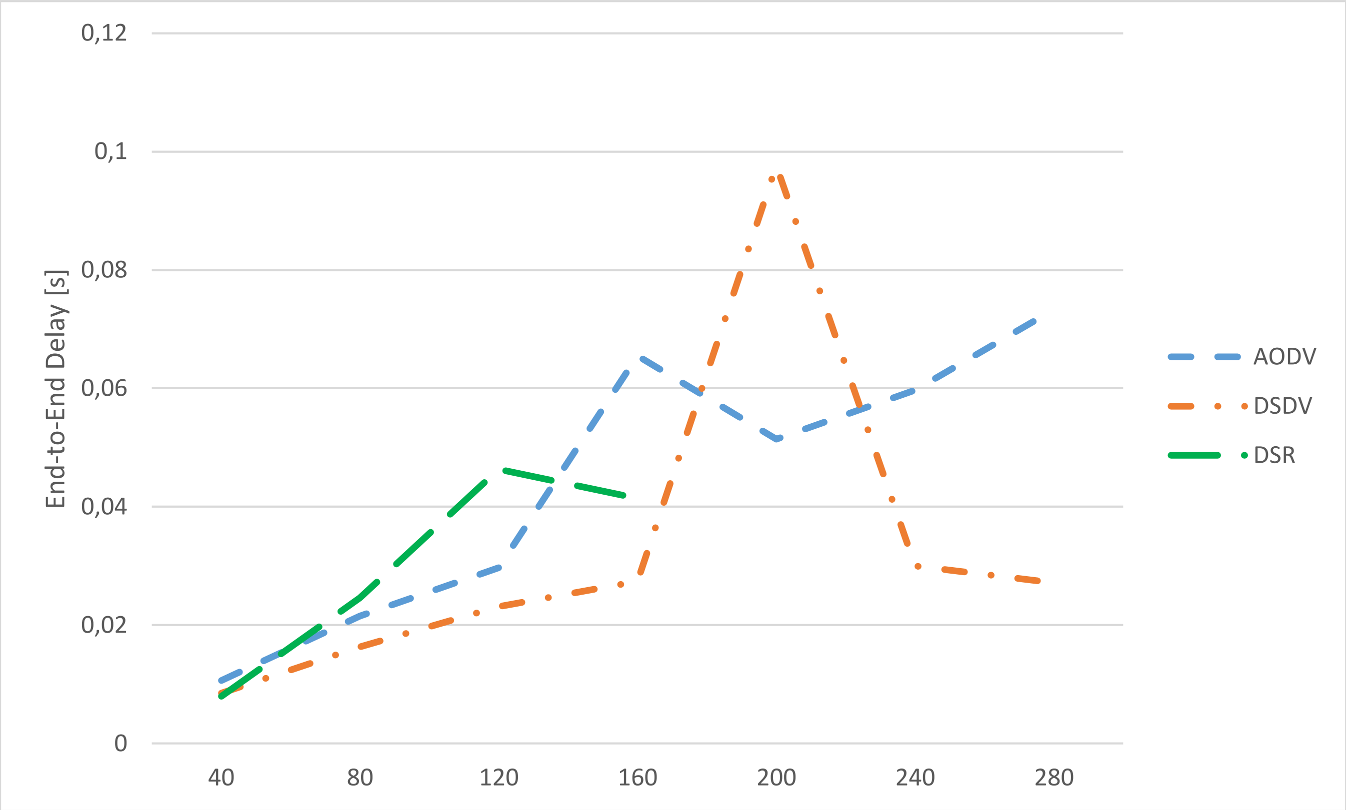
	Throughtput [bit/sec]		
Nº Nodes	AODV	DSDV	DSR
40	3804,22	3801,31	3170,35
80	3803,92	3774,22	3168,73
120	3803,08	3611,71	3173,31
160	3787,37	3367,91	3170,36
200	3804,41	3062,07	
240	3803,49	2729,55	
280	3803,6	2283,86	



SIMULATION RESULTS

SCENARIO 1

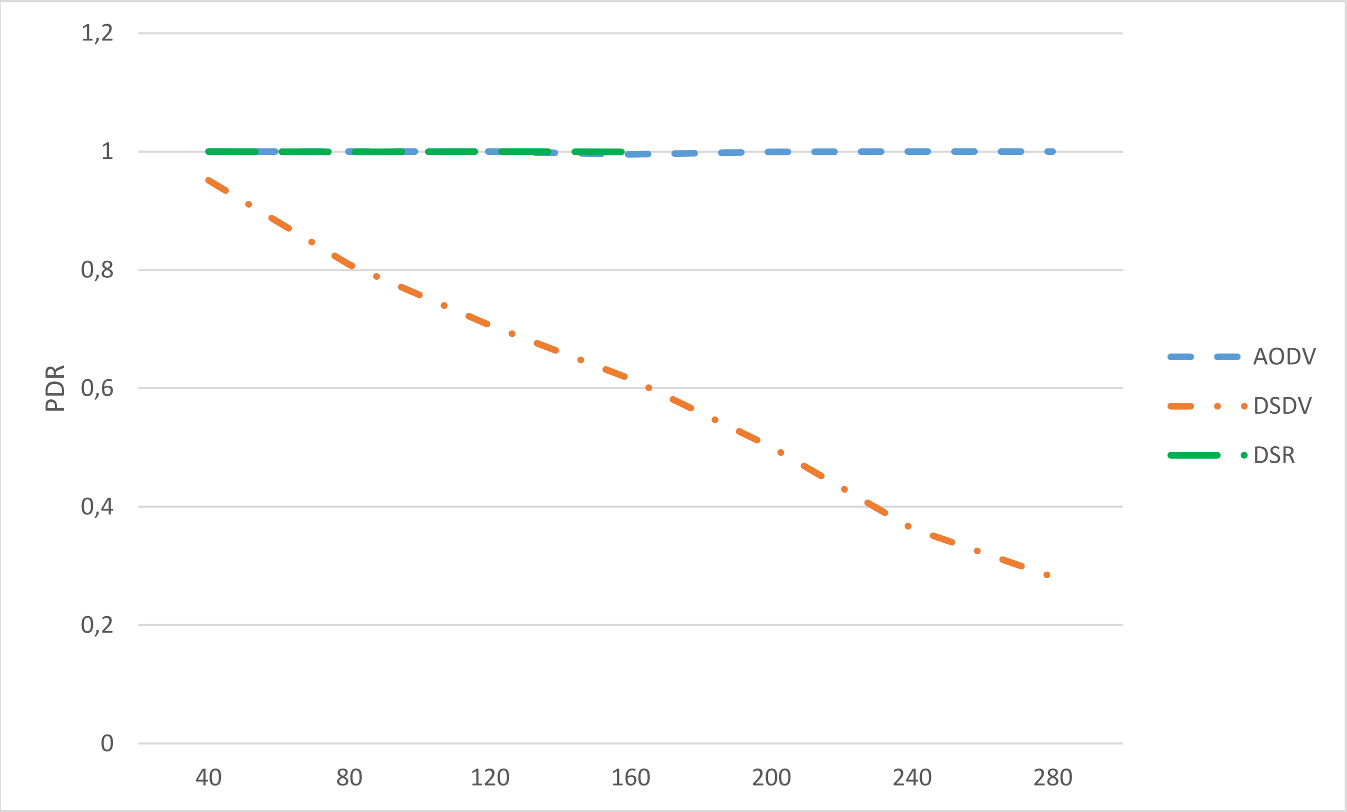
	End to End Delay [sec]		
Nº Nodes	AODV	DSDV	DSR
40	0,010631	0,008497	0,007976
80	0,021532	0,016308	0,024601
120	0,029694	0,023101	0,046305
160	0,065495	0,027406	0,041421
200	0,051436	0,097641	
240	0,059681	0,029999	
280	0,073309	0,027166	



SIMULATION RESULTS

SCENARIO 1

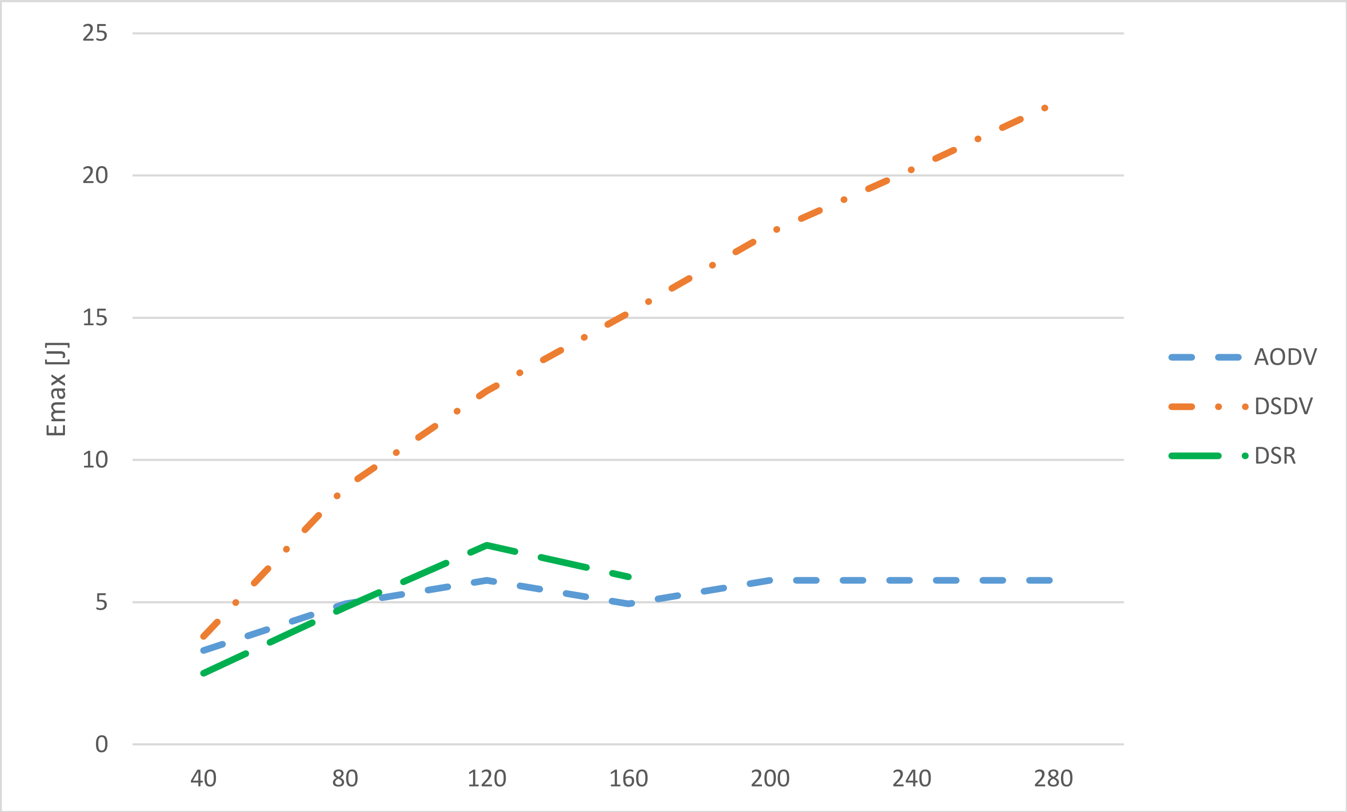
	PDR		
Nº Nodes	AODV	DSDV	DSR
40	1	0,951789	1
80	1	0,809145	0,999503
120	1	0,706262	1
160	0,995529	0,615996	0,999503
200	0,999503	0,500994	
240	1	0,36332	
280	1	0,281312	



SIMULATION RESULTS

SCENARIO 1

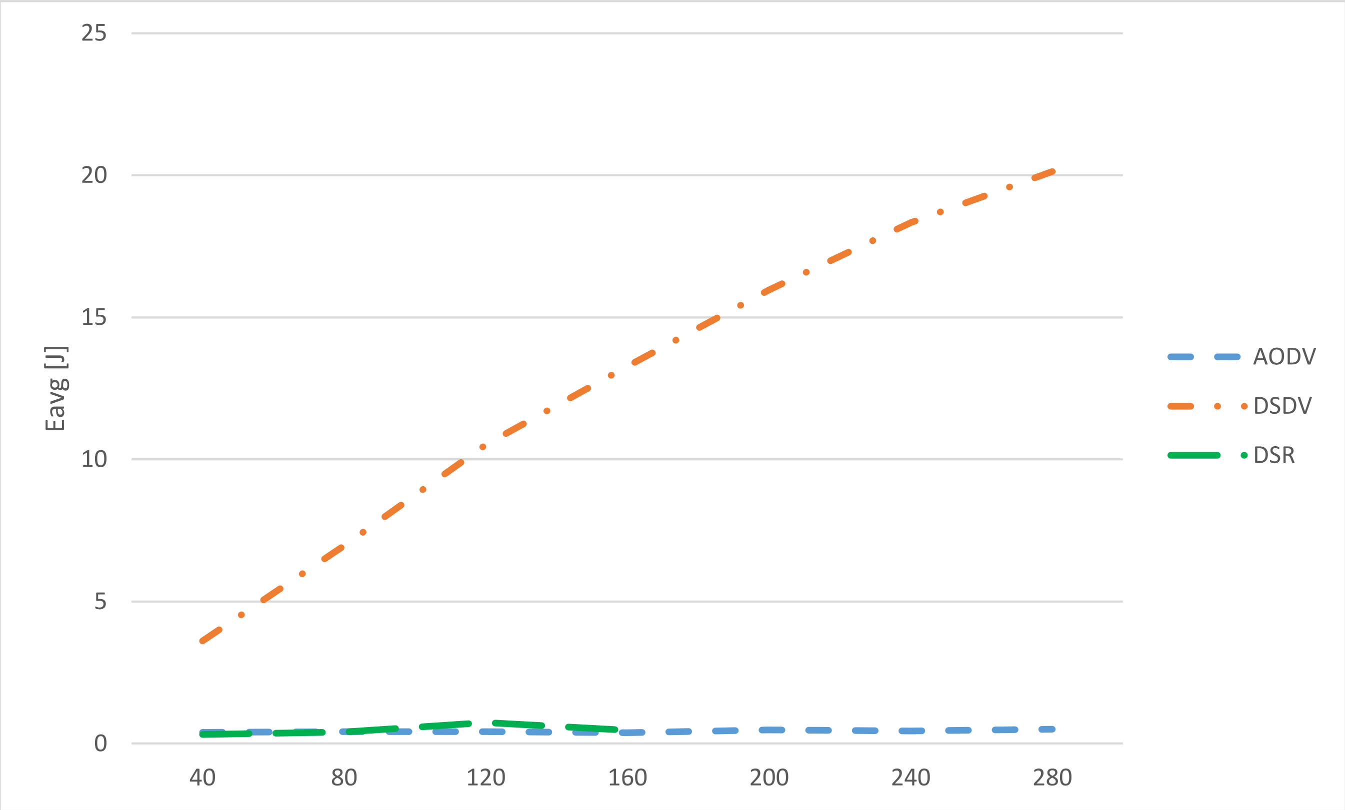
	Emax [J]		
Nº Nodes	AODV	DSDV	DSR
40	3,29796	3,7915	2,49898
80	4,9435	9,03365	4,81743
120	5,76667	12,4303	6,99889
160	4,93765	15,1591	5,8853
200	5,76968	17,9943	
240	5,76686	20,2055	
280	5,766870	22,5133	



SIMULATION RESULTS

SCENARIO 1

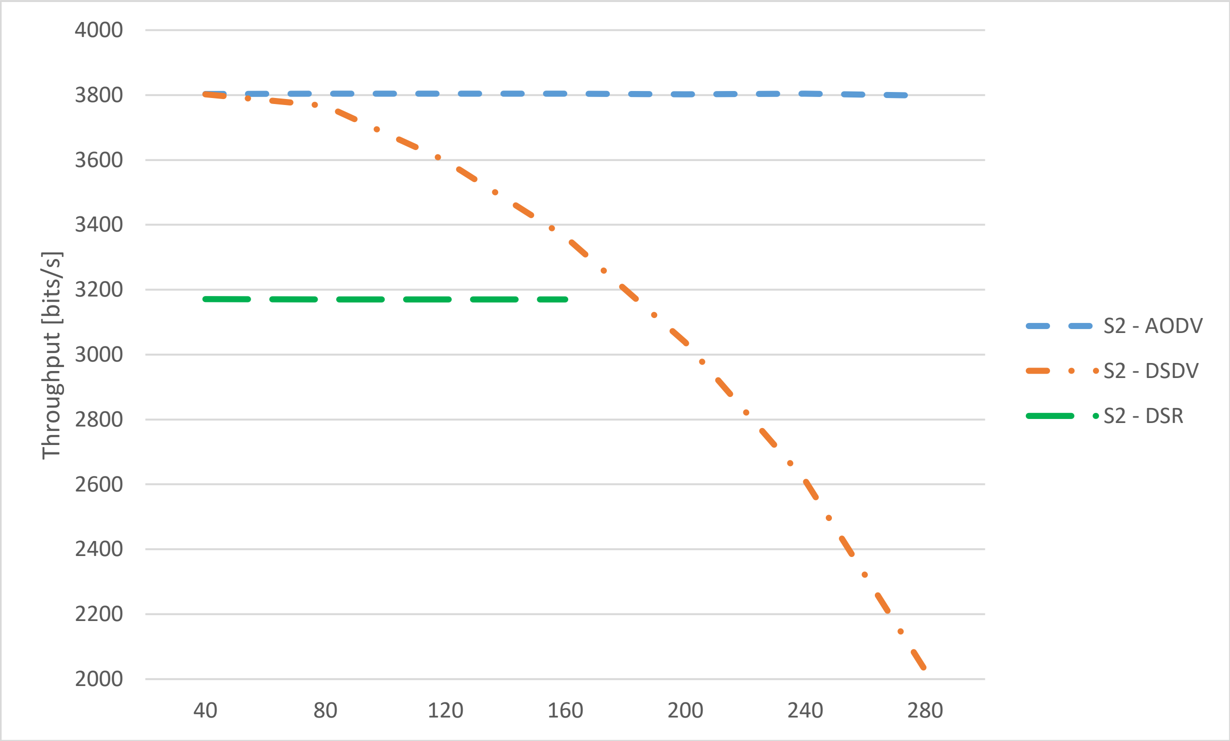
	Eavg [J]		
Nº Nodes	AODV	DSDV	DSR
40	0,385167	3,61231	0,319702
80	0,420761	6,95888	0,397156
120	0,412583	10,5165	0,73549
160	0,374092	13,2809	0,467945
200	0,474593	15,9676	
240	0,440988	18,3344	
280	0,502662	20,1335	



SIMULATION RESULTS

SCENARIO 2

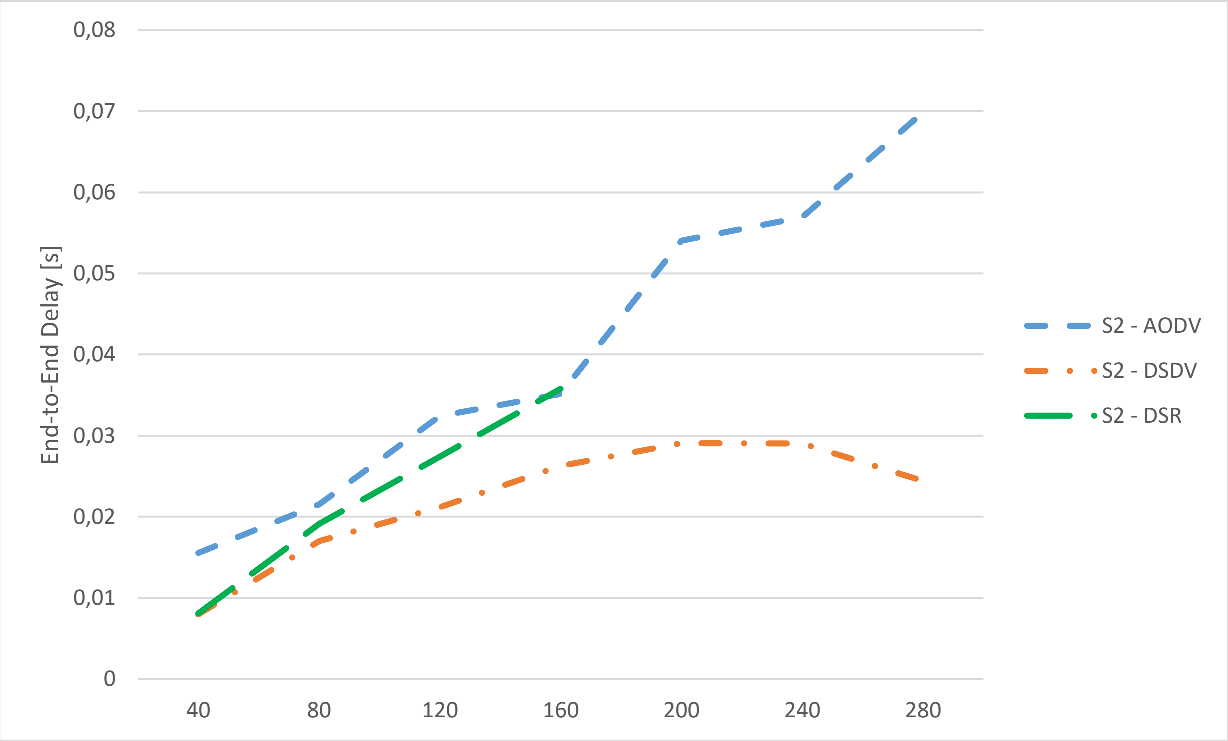
	Throughtput [bits/sec]		
Nº Nodes	AODV	DSDV	DSR
40	3803,63	3802,46	3171,32
80	3804,58	3766,96	3170,29
120	3804,77	3597,9	3170,2
160	3804,5	3363,77	3169,73
200	3802,49	3037,54	
240	3804,19	2612,4	
280	3798,09	2028,14	



SIMULATION RESULTS

SCENARIO 2

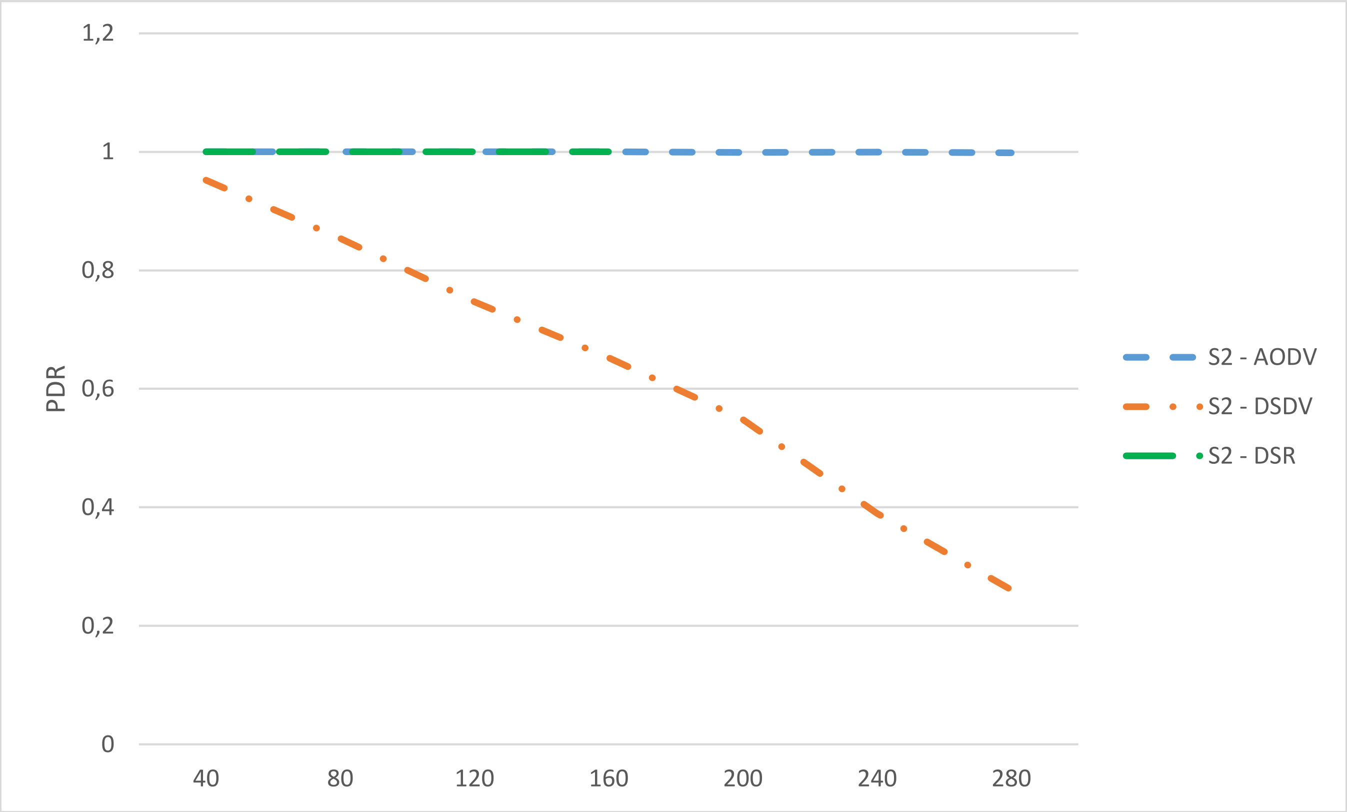
	End to End Delay [sec]		
Nº Nodes	AODV	DSDV	DSR
40	0,0155364	0,00795274	0,008084
80	0,02154	0,016994	0,019129
120	0,0324034	0,0211571	0,0273929
160	0,0351536	0,0262474	0,035773
200	0,054045	0,0290687	
240	0,056932	0,0290415	
280	0,069885	0,0244254	



SIMULATION RESULTS

SCENARIO 2

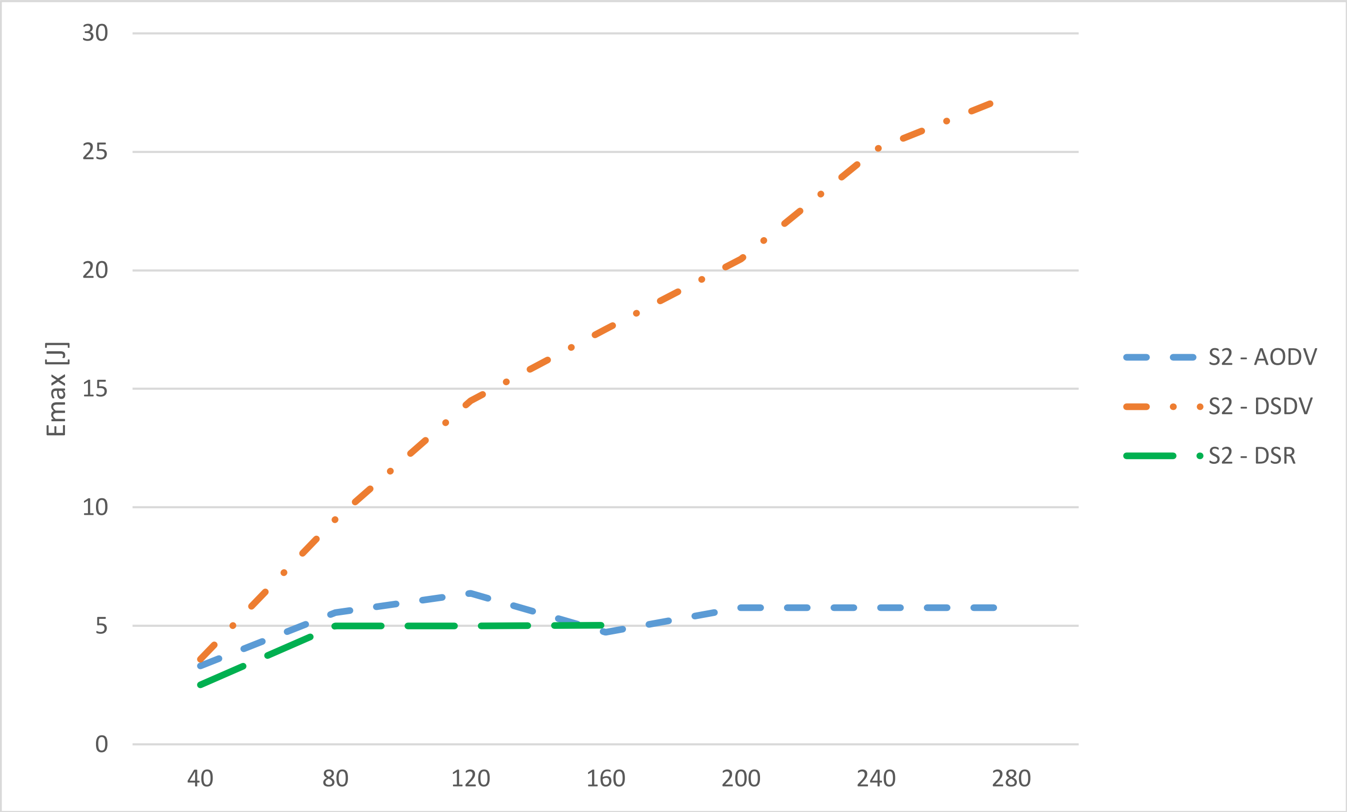
	PDR		
Nº Nodes	AODV	DSDV	DSR
40	1	0,95231	1
80	1	0,853877	1
120	1	0,747018	1
160	1	0,652584	1
200	0,999006	0,548708	
240	0,999503	0,389662	
280	0,998509	0,260934	



SIMULATION RESULTS

SCENARIO 2

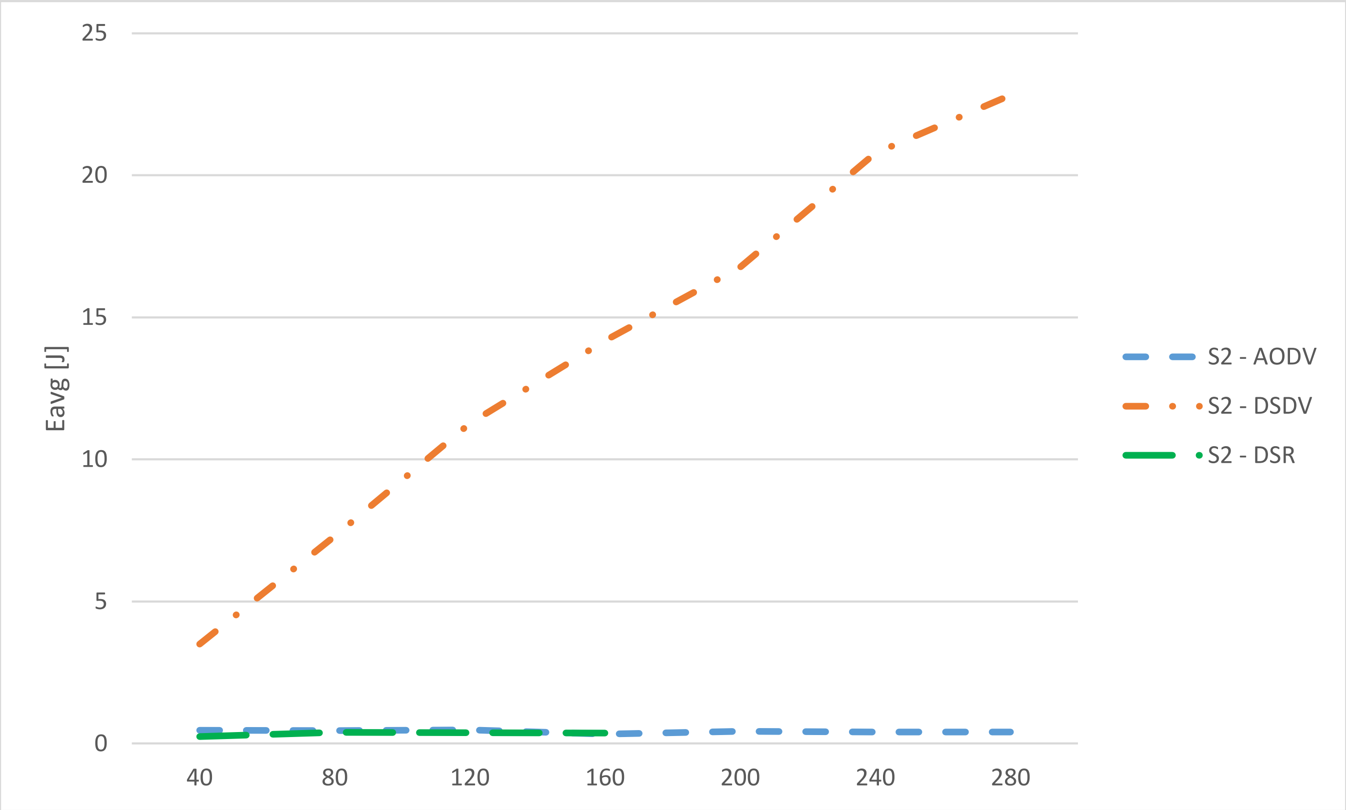
		Emax [J]	
Nº Nodes	AODV	DSDV	DSR
40	3,30231	3,59088	2,51204
80	5,55543	9,49463	4,99746
120	6,37946	14,4954	3,84762
160	4,73151	17,5074	5,03324
200	5,77038	20,4721	
240	5,76761	25,099	
280	5,76234	27,3819	



SIMULATION RESULTS

SCENARIO 2

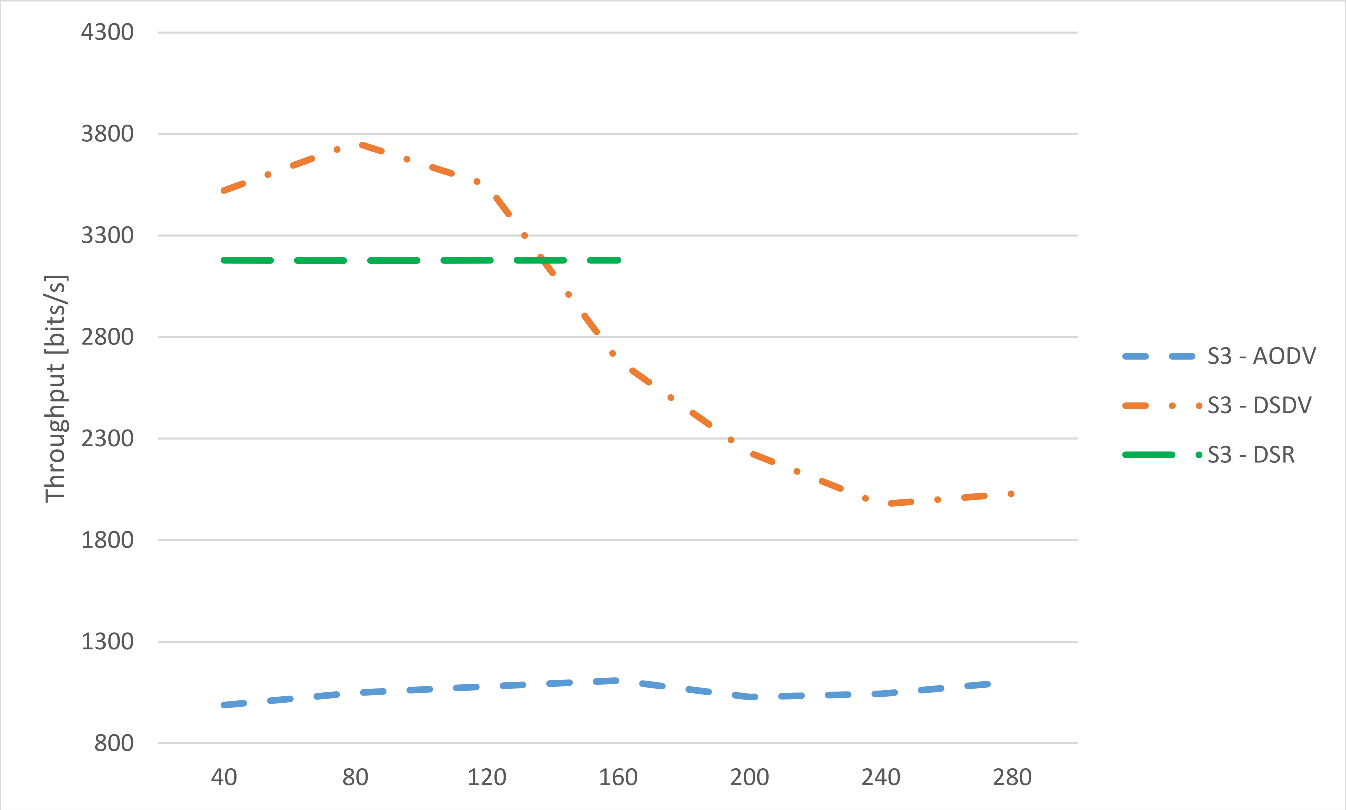
	Eavg [J]		
Nº Nodes	AODV	DSDV	DSR
40	0,233982	2,59037	0,242266
80	0,44958	7,29463	0,385787
120	0,373426	4,923967	0,25653
160	0,468213	7,89845	0,362658
200	0,427629	8,95975	
240	0,396824	10,06805	
280	0,407503	22,8242	



SIMULATION RESULTS

SCENARIO 3

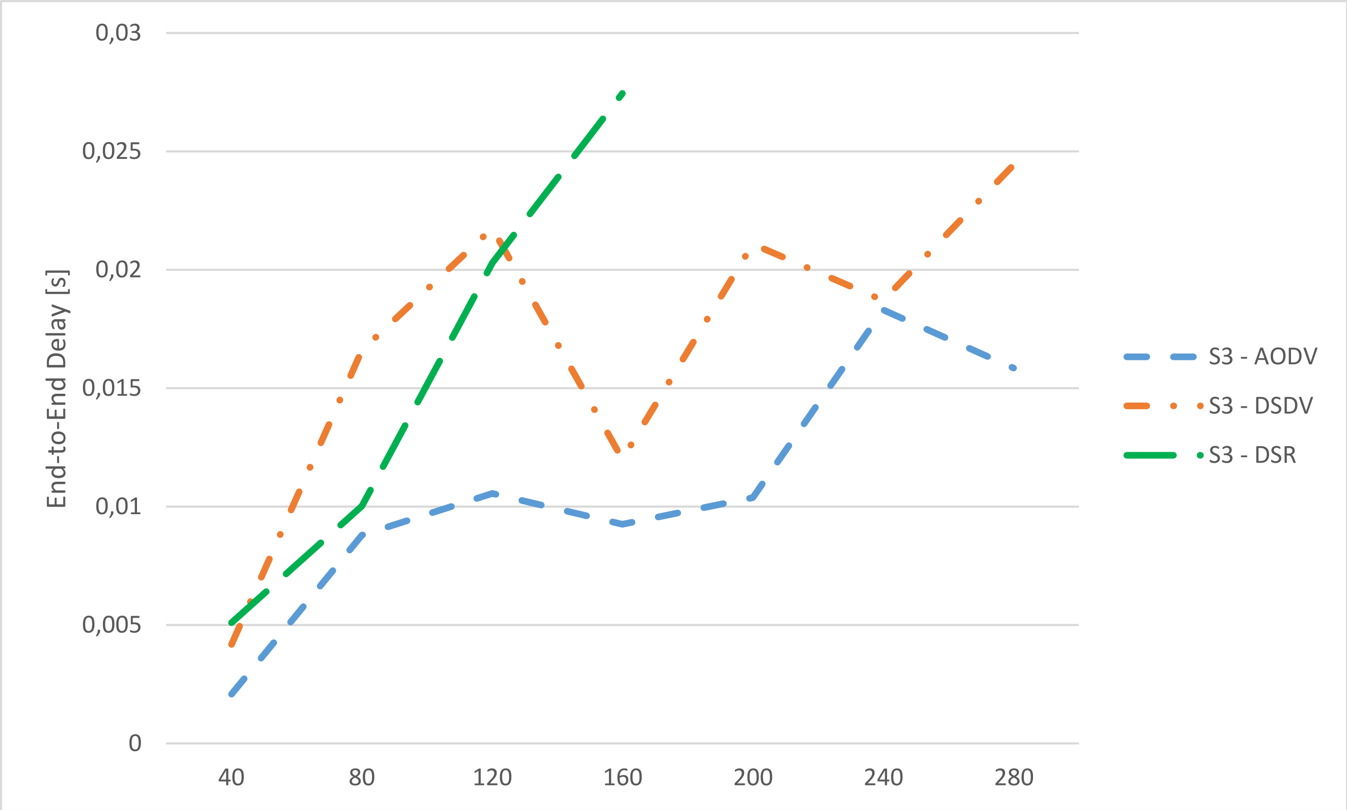
	Throughtput [bits/sec]		
Nº Nodes	AODV	DSDV	DSR
40	986,884	3522,45	3178,26
80	1048,74	3756,9	3176,07
120	1078,41	3550,74	3178,12
160	1107,68	2683,8	3178,77
200	1026,52	2229,88	
240	1042,07	1977,37	
280	1100,88	2028,14	



SIMULATION RESULTS

SCENARIO 3

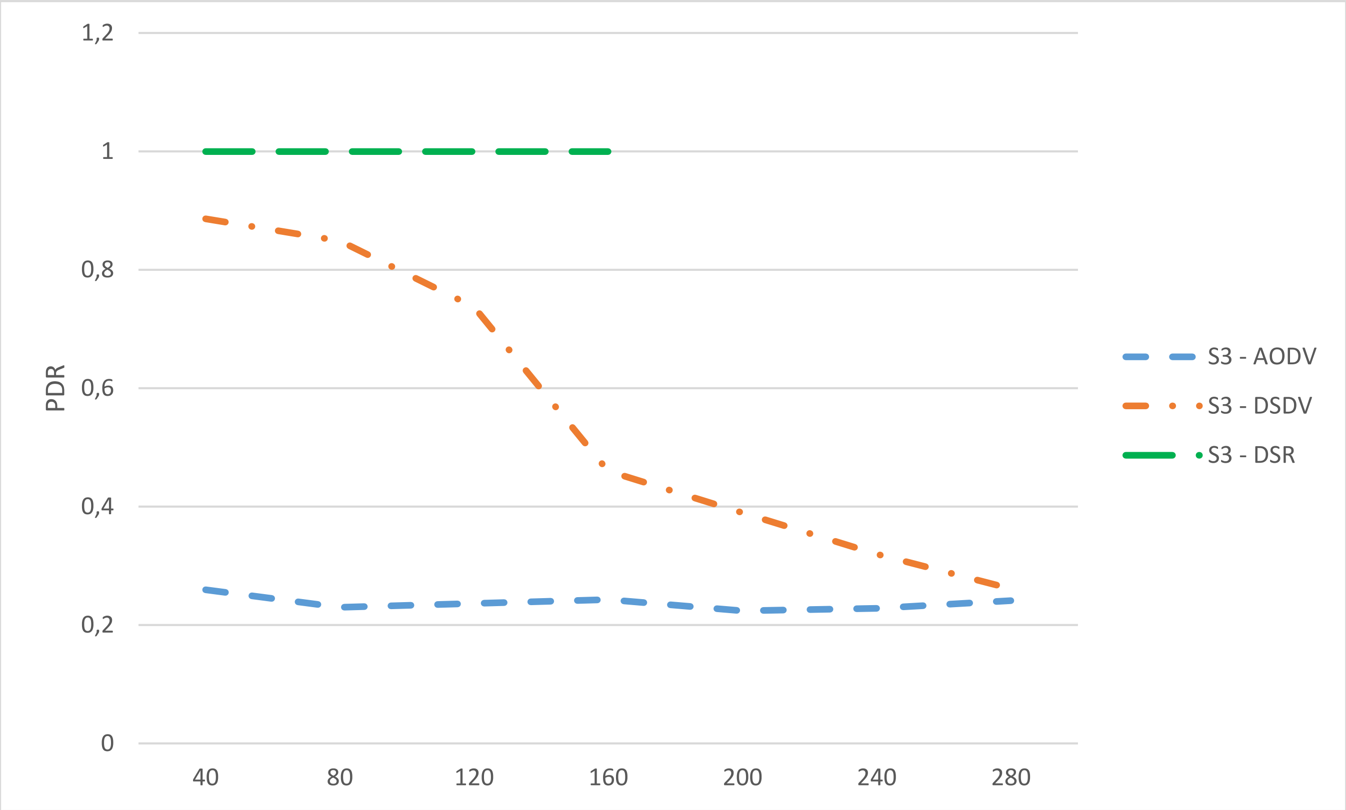
	End to End Delay [sec]		
Nº Nodes	AODV	DSDV	DSR
40	0,002072	0,004174	0,005098
80	0,008792	0,016609	0,010026
120	0,010551	0,021755	0,020293
160	0,009247	0,012009	0,027455
200	0,010374	0,021089	
240	0,018299	0,018704	
280	0,015852	0,024425	



SIMULATION RESULTS

SCENARIO 3

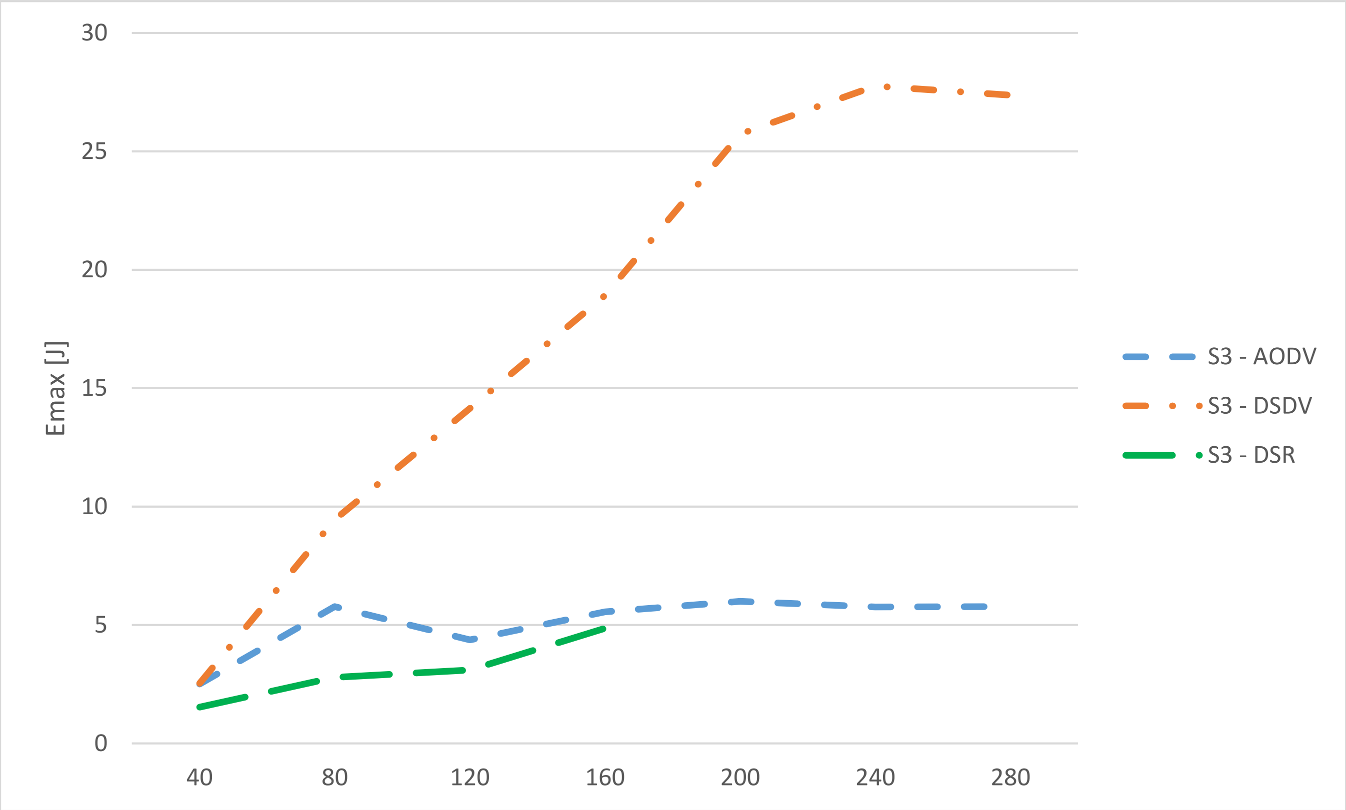
	PDR		
Nº Nodes	AODV	DSDV	DSR
40	0,259443	0,886183	1
80	0,229622	0,848982	1
120	0,235966	0,737078	1
160	0,242921	0,459742	1
200	0,223547	0,389662	
240	0,228018	0,319583	
280	0,241054	0,260934	



SIMULATION RESULTS

SCENARIO 3

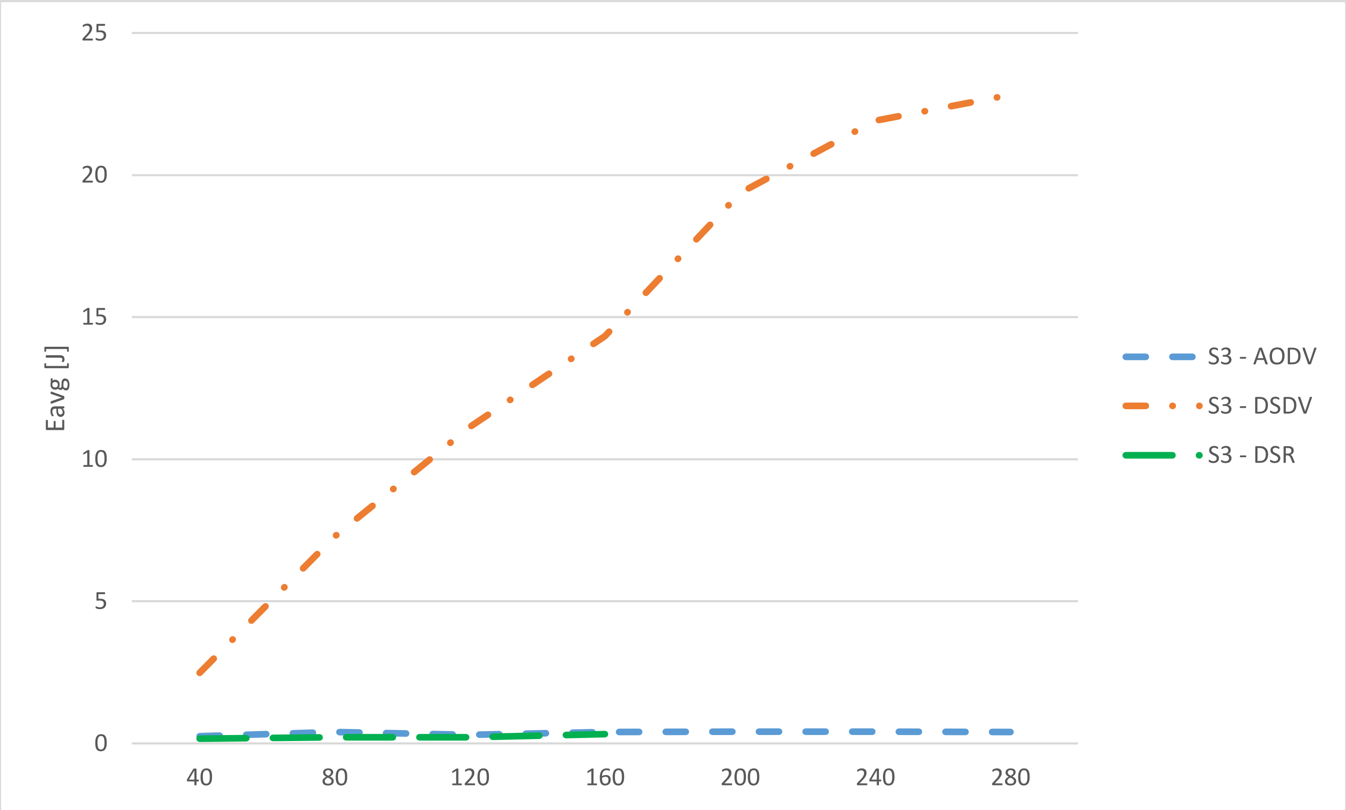
	Emax [J]		
Nº Nodes	AODV	DSDV	DSR
40	2,50647	2,53146	1,52791
80	5,7795	9,44977	2,78052
120	4,36316	14,1429	3,09319
160	5,55477	18,9066	4,85449
200	5,99979	25,738	
240	5,765	27,7664	
280	5,76608	27,3819	



SIMULATION RESULTS

SCENARIO 3

		Eavg [J]	
Nº Nodes	AODV	DSDV	DSR
40	0,247702	2,47462	0,164301
80	0,401848	7,27264	0,217044
120	0,302166	11,1413	0,211215
160	0,393544	14,3279	0,322888
200	0,405801	19,3771	
240	0,411209	21,9111	
280	0,397026	22,8242	



SIMULATION RESULTS

NEXT STEPS

- Add more protocols in the evaluation scope;
- Different node deployment strategies;
- Improve energy model;

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