Bonus Report: Failure Models in Gossip and Push-Sum Protocols

Failure Model Implementation

For the bonus component, we introduced a failure model to study the resilience of the Gossip and Push-Sum algorithms. The model is controlled by a single parameter: `kill_percent`.

After the network of n nodes is initialized and connected according to the specified topology, `kill_percent` of the total nodes are randomly selected and terminated. This action creates an inconsistent state in the network, preventing the terminated nodes from participating in any further communication.

The objective of this implementation is to observe and compare the performance, convergence speed, and accuracy of both the Push-Sum and Gossip algorithms under these faulty network conditions.

Push-Sum Algorithm: Observations

We experimented with the Push-Sum algorithm by varying the `kill_percent` parameter.

- **Convergence Speed:** As `kill_percent` was increased, the overall time to convergence for the remaining active nodes decreased.
- **Accuracy:**
  - With a `kill_percent` of 0 (no node failures), the converged values were extremely accurate, matching the expected mathematical average of all node values.
  - As `kill_percent` increased, the final converged value began to diverge from the expected value. The loss of nodes and their initial values means the network is calculating an average over a smaller, incomplete set of data.
- **Topology Impact:** The **line** topology was the most significantly affected by the `kill_percent` parameter. The linear dependency means a single node failure can partition the network.
- **Resilience:** It was interesting to observe that even with a significant number of nodes being terminated, the algorithm was still able to produce a converged value with surprising accuracy. This demonstrates the inherent resilience of the Push-Sum protocol.

Gossip Algorithm: Observations

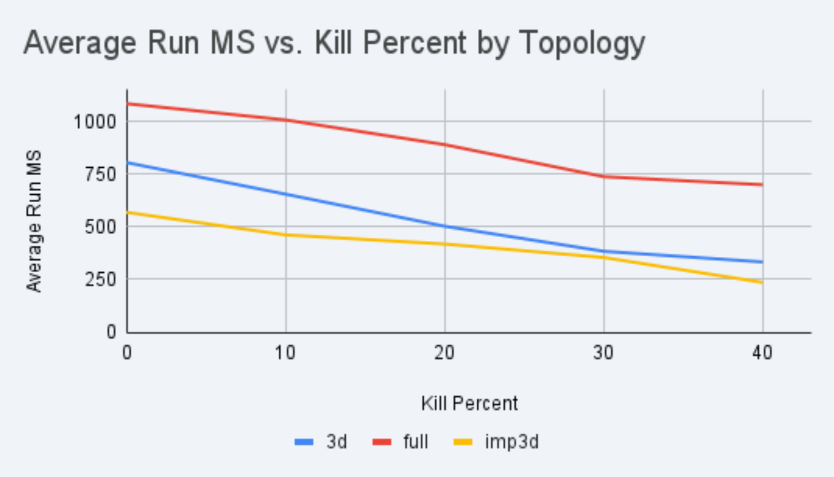
For the Gossip protocol, we defined a `gossip_convergence_threshold` of 3000, representing the number of times a node must receive the same gossip before it considers its state converged.

- **Convergence Speed:** Nodes achieved convergence relatively quickly. This is likely due to the rapid and redundant exchange of messages between local neighbors, which efficiently propagates the gossip through the active parts of the network.
- **Line Topology Failure:** As expected, the line topology exhibited a critical failure case. If a node's immediate neighbors on both sides were terminated, that node became completely isolated. With no neighbors to communicate with, it could never reach the convergence threshold, causing the program to hang.

Plots and Data

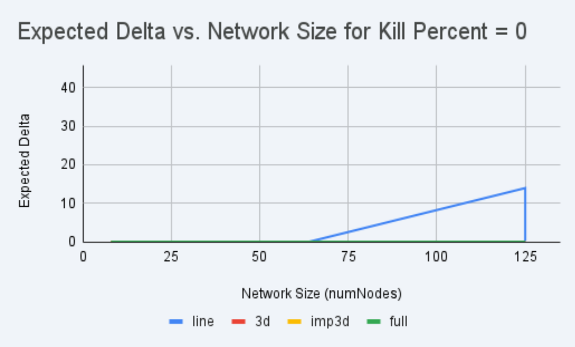
Gossip

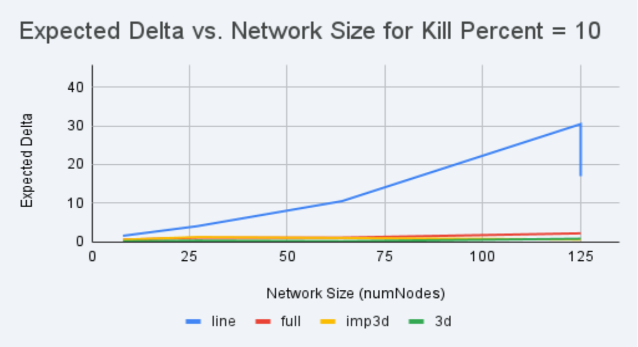
Plots with change in program runtime with respect to increasing kill percent.

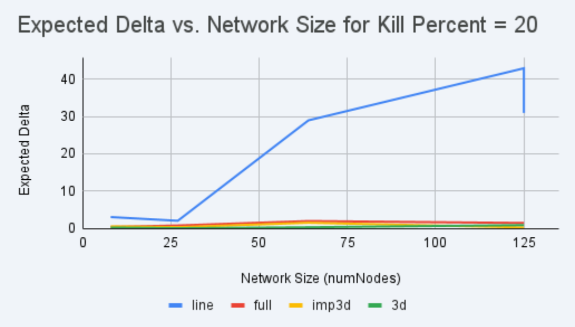


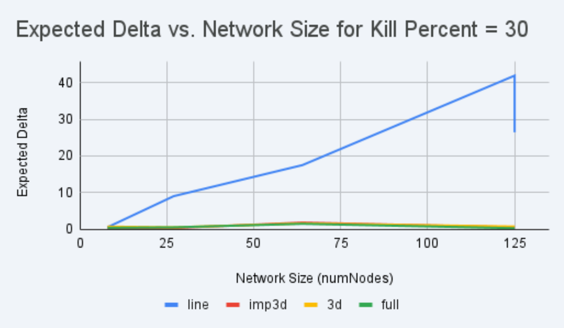
Push Sum

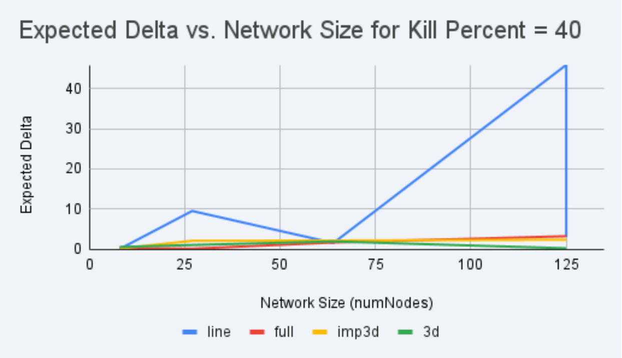
Plots with increasing kill percent parameter for different topologies showing increasing delta between converged and expected value.











Raw Data:

Gossip:

numNodes	topology	algorithm	average_3runs_ms	kill_percent
27	3d	gossip	163.989	0
27	3d	gossip	162.832667	10
27	3d	gossip	146.448667	20

27	3d	gossip	111.694	30
27	3d	gossip	111.65	40
27	imp3d	gossip	162.640667	0
27	imp3d	gossip	129.04	10
27	imp3d	gossip	129.884	20
27	imp3d	gossip	111.761	30
27	imp3d	gossip	113.095667	40
27	full	gossip	232.116667	0
27	full	gossip	214.483667	10
27	full	gossip	214.575333	20
27	full	gossip	163.961667	30
27	full	gossip	181.070333	40
64	3d	gossip	452.305667	0
64	3d	gossip	366.879667	10
64	3d	gossip	282.283333	20
64	3d	gossip	198.541	30
64	3d	gossip	182.198333	40
64	imp3d	gossip	368.380667	0
64	imp3d	gossip	317.049	10
64	imp3d	gossip	248.181667	20
64	imp3d	gossip	230.963333	30
64	imp3d	gossip	128.35	40
64	full	gossip	555.18	0
64	full	gossip	487.690667	10

64	full	gossip	470.270333	20
64	full	gossip	366.894333	30
64	full	gossip	350.409667	40
125	3d	gossip	962.632333	0
125	3d	gossip	776.248	10
125	3d	gossip	622.056	20
125	3d	gossip	434.9	30
125	3d	gossip	350.496667	40
125	imp3d	gossip	657.575333	0
125	imp3d	gossip	573.252667	10
125	imp3d	gossip	469.172667	20
125	imp3d	gossip	351.548	30
125	imp3d	gossip	232.883	40
125	full	gossip	1134.08867	0
125	full	gossip	1171.28	10
125	full	gossip	1050.55767	20
125	full	gossip	846.466333	30
125	full	gossip	759.322	40
216	3d	gossip	1648.98533	0
216	3d	gossip	1320.06867	10
216	3d	gossip	964.530333	20
216	3d	gossip	793.118	30
216	3d	gossip	690.862667	40
216	full	gossip	2426.14733	0

216	full	gossip	2164.26367	10
216	full	gossip	1832.211	20
216	full	gossip	1580.409	30
216	full	gossip	1513.52	40
216	imp3d	gossip	1092.02433	0
216	imp3d	gossip	831.342333	10
216	imp3d	gossip	829.580667	20
216	imp3d	gossip	726.367333	30
216	imp3d	gossip	471.101333	40

Push Sum:

numNodes	topology	algorithm	run_ms	convergence_value	expected_value	expected_delta	kill_percent
125	line	push-sum	61.346	109	63	46	40
125	line	push-sum	112.387	106	63	43	20
125	line	push-sum	62.701	21	63	42	30
125	line	push-sum	61.496	94	63	31	20
125	line	push-sum	113.087	93.5	63	30.5	10
64	line	push-sum	60.849	3.5	32.5	29	20
125	line	push-sum	61.909	36.5	63	26.5	30
64	line	push-sum	61.152	15	32.5	17.5	30
125	line	push-sum	622.258	80	63	17	10
125	line	push-sum	5314.866	49.05	63	13.95	0
64	line	push-sum	111.468	22	32.5	10.5	10
27	line	push-sum	63.042	4.5	14	9.5	40

27	line	push-sum	60.425	23	14	9	30
27	line	push-sum	61.754	10	14	4	10
125	full	push-sum	111.276	66.19	63	3.19	40
125	line	push-sum	61.287	60	63	3	40
8	line	push-sum	60.619	1.5	4.5	3	20
125	imp3d	push-sum	417.351	60.69	63	2.31	40
125	full	push-sum	164.084	65.14	63	2.14	10
64	imp3d	push-sum	162.199	30.39	32.5	2.11	40
27	imp3d	push-sum	60.327	11.94	14	2.06	40
27	line	push-sum	60.253	16	14	2	20
64	full	push-sum	63.881	30.57	32.5	1.93	20
64	3d	push-sum	674.594	30.61	32.5	1.89	40
64	imp3d	push-sum	213.334	30.73	32.5	1.77	30
64	full	push-sum	60.285	30.87	32.5	1.63	40
64	3d	push-sum	213.199	34.04	32.5	1.54	30
8	line	push-sum	61.757	6	4.5	1.5	10
64	line	push-sum	61.976	31	32.5	1.5	40
64	imp3d	push-sum	163.095	33.96	32.5	1.46	20
64	full	push-sum	60.313	33.93	32.5	1.43	30
125	full	push-sum	163.181	61.59	63	1.41	20
27	imp3d	push-sum	60.451	15.17	14	1.17	10
64	full	push-sum	111.164	31.47	32.5	1.03	10
27	full	push-sum	61.165	15	14	1	10
27	3d	push-sum	60.809	13	14	1	40

64	imp3d	push-sum	162.503	33.43	32.5	0.93	10
125	3d	push-sum	571.227	63.83	63	0.83	20
125	3d	push-sum	621.201	62.26	63	0.74	10
27	full	push-sum	60.149	14.73	14	0.73	20
125	3d	push-sum	521.853	62.3	63	0.7	30
8	3d	push-sum	61.088	3.83	4.5	0.67	30
125	imp3d	push-sum	265.08	63.53	63	0.53	10
8	imp3d	push-sum	60.921	4	4.5	0.5	10
8	full	push-sum	60.077	4	4.5	0.5	10
8	imp3d	push-sum	61.802	4	4.5	0.5	20
8	3d	push-sum	60.895	5	4.5	0.5	40
8	line	push-sum	60.263	4	4.5	0.5	30
125	imp3d	push-sum	213.266	62.51	63	0.49	30
27	3d	push-sum	111.24	14.47	14	0.47	30
27	full	push-sum	61.177	14.47	14	0.47	30
8	full	push-sum	60.23	4.83	4.5	0.33	20
8	full	push-sum	61.273	4.17	4.5	0.33	30
8	full	push-sum	60.116	4.8	4.5	0.3	40
27	imp3d	push-sum	62.517	14.27	14	0.27	20
27	imp3d	push-sum	60.353	13.74	14	0.26	30
125	line	push-sum	23935.739	63.26	63	0.26	0
27	3d	push-sum	60.268	13.75	14	0.25	10
64	3d	push-sum	216.164	32.75	32.5	0.25	20
125	full	push-sum	112.284	62.78	63	0.22	30

125	imp3d	push-sum	468.298	62.8	63	0.2	20
125	3d	push-sum	774.261	62.83	63	0.17	40
8	3d	push-sum	60.113	4.67	4.5	0.17	20
8	imp3d	push-sum	60.428	4.67	4.5	0.17	30
8	imp3d	push-sum	60.264	4.4	4.5	0.1	40
64	3d	push-sum	213.241	32.41	32.5	0.09	10
8	3d	push-sum	60.269	4.57	4.5	0.07	10
27	full	push-sum	60.35	14.06	14	0.06	40
8	3d	push-sum	60.181	4.5	4.5	0	0
8	imp3d	push-sum	61.877	4.5	4.5	0	0
8	full	push-sum	60.796	4.5	4.5	0	0
27	3d	push-sum	61.143	14	14	0	0
27	imp3d	push-sum	60.006	14	14	0	0
27	full	push-sum	61.504	14	14	0	0
27	3d	push-sum	111.225	14	14	0	20
64	3d	push-sum	214.902	32.5	32.5	0	0
64	imp3d	push-sum	111.475	32.5	32.5	0	0
64	full	push-sum	112.511	32.5	32.5	0	0
125	3d	push-sum	573.6	63	63	0	0
125	imp3d	push-sum	315.473	63	63	0	0
125	full	push-sum	163.942	63	63	0	0
8	line	push-sum	60.768	4.5	4.5	0	0
8	line	push-sum	60.027	4.5	4.5	0	40
27	line	push-sum	571.517	14	14	0	0

64	line	push-sum	5262.746	32.5	32.5	0	0