

TABLE VIII
RESULTS WITH SIMULATED SCENARIO d_1 WITH PACKET LOSS

Model	Normal		Loss 10%		Loss 20%		Loss 30%	
	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	90.02%	90.03%	61.62%(28.40%↓)	58.57%(31.46%↓)	53.59%(36.43%↓)	50.74%(39.29%↓)	51.45%(38.57%↓)	50.74%(39.29%↓)
LSTM	90.61%	90.58%	62.11%(28.50%↓)	57.56%(33.02%↓)	53.23%(37.38%↓)	48.29%(42.29%↓)	52.66%(37.95%↓)	47.16%(43.42%↓)
GRU	89.13%	89.09%	59.72%(29.41%↓)	56.93%(32.16%↓)	47.36%(41.77%↓)	46.10%(42.99%↓)	43.52%(45.61%↓)	43.32%(45.77%↓)
TST	94.25%	94.23%	64.91%(29.34%↓)	60.51%(33.72%↓)	58.86%(35.39%↓)	53.96%(40.27%↓)	58.01%(36.24%↓)	51.32%(42.91%↓)
SDAE	72.71%	65.83%	60.36%(12.35%↓)	53.26%(12.57%↓)	55.14%(17.57%↓)	47.09%(18.74%↓)	55.99%(16.72%↓)	46.58%(19.25%↓)
FS-Net	91.91%	91.09%	87.65%(4.26%↓)	86.01%(5.08%↓)	80.52%(11.39%↓)	77.41%(13.68%↓)	71.46%(20.45%↓)	66.12%(24.97%↓)
Average	88.11%	86.81%	66.06%(22.04%↓)	62.14%(24.67%↓)	58.12%(29.99%↓)	53.93%(32.88%↓)	55.52%(32.59%↓)	50.87%(35.94%↓)

TABLE IX
SIMULATED RESULTS OF SCENARIO d_2 WITH PACKET LOSS.

Model	Normal		Loss 10%		Loss 20%		Loss 30%	
	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	99.80%	99.80%	88.88%(10.92%↓)	88.92%(10.88%↓)	77.33%(22.47%↓)	77.54%(22.26%↓)	64.26%(35.54%↓)	64.62%(35.18%↓)
LSTM	99.30%	99.30%	70.23%(29.07%↓)	69.72%(29.58%↓)	55.60%(43.70%↓)	54.79%(44.51%↓)	45.46%(53.84%↓)	44.48%(54.82%↓)
GRU	99.23%	99.23%	71.16%(28.07%↓)	70.76%(28.47%↓)	56.11%(43.12%↓)	55.24%(43.99%↓)	46.14%(53.09%↓)	44.67%(54.56%↓)
TST	99.80%	99.80%	93.22%(6.58%↓)	93.24%(6.56%↓)	82.81%(16.99%↓)	82.99%(16.81%↓)	72.01%(27.79%↓)	72.43%(27.37%↓)
SDAE	96.32%	96.32%	62.08%(34.24%↓)	61.68%(34.64%↓)	47.25%(49.07%↓)	46.70%(49.62%↓)	38.78%(57.54%↓)	38.22%(58.10%↓)
FS-Net	99.89%	99.89%	95.63%(4.26%↓)	95.66%(4.23%↓)	90.41%(9.48%↓)	90.52%(9.37%↓)	83.66%(16.23%↓)	83.87%(16.02%↓)
Average	99.06%	99.06%	80.20%(18.86%↓)	80.00%(19.06%↓)	68.25%(30.81%↓)	67.96%(31.09%↓)	58.39%(40.67%↓)	58.05%(41.01%↓)

TABLE X
RESULTS OF SIMULATED SCENARIO d_3 WITH PACKET LOSS.

Model	Normal		Loss 10%		Loss 20%		Loss 30%	
	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	84.26%	84.24%	67.99%(16.27%↓)	67.87%(16.37%↓)	61.15%(23.11%↓)	60.60%(23.64%↓)	56.38%(27.88%↓)	55.27%(28.97%↓)
LSTM	92.17%	92.18%	63.79%(28.38%↓)	63.37%(28.81%↓)	54.87%(37.30%↓)	53.98%(38.20%↓)	48.79%(43.38%↓)	48.33%(43.85%↓)
GRU	84.10%	84.05%	62.30%(21.80%↓)	62.04%(22.01%↓)	54.22%(29.88%↓)	53.97%(30.08%↓)	47.21%(36.89%↓)	47.39%(36.66%↓)
TST	95.93%	95.93%	72.51%(23.42%↓)	72.14%(23.79%↓)	62.6%(33.33%↓)	61.55%(34.38%↓)	56.94%(38.99%↓)	55.27%(40.66%↓)
SDAE	74.62%	74.44%	63.96%(10.66%↓)	63.53%(10.91%↓)	56.92%(17.70%↓)	55.93%(18.51%↓)	51.04%(23.58%↓)	49.72%(24.72%↓)
FS-Net	81.51%	78.36%	77.84%(3.67%↓)	74.31%(4.05%↓)	72.11%(9.40%↓)	67.71%(10.65%↓)	66.06%(15.45%↓)	60.79%(17.57%↓)
Average	85.43%	84.87%	68.07%(17.37%↓)	67.21%(17.66%↓)	60.31%(25.12%↓)	58.96%(25.91%↓)	54.40%(31.03%↓)	52.80%(32.07%↓)

IX. APPENDIX

APPENDIX A

ADDITIONAL RESULTS ON PACKET LOSS

The classifying results of simulated packet loss on the other three scenarios are shown in Tables VIII-XI.

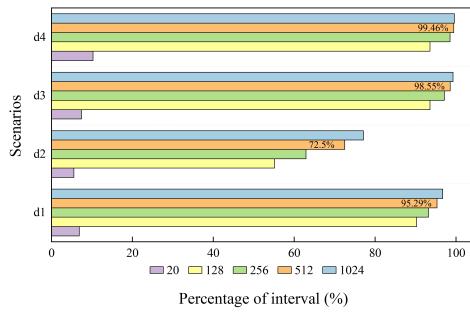


Fig. 15. Distribution of session length intervals for 4 scenarios.

And the classifying results of simulated packet loss on the other three scenarios are shown in Tables XII, XIII and XIV.

APPENDIX B

ADDITIONAL RESULTS ON SDA

The classifying results of simulated feature imputation on the other three scenarios are shown in Tables XV-XVIII.

The classifying results of real-word feature imputation on the other three scenarios are shown in Tables XIX, XX and XXI.

APPENDIX C

ADDITIONAL RESULTS ON SFDA

The classifying results on the other three scenarios are shown in Tables XXVII- XXX and Fig. 18.

Results on scenario d_1 in SFDA. As shown in the Table XXVII, the average performance of TFM models on d_1 improves 11.68%-15.06% accuracy and 13.16%-16.92% F1 score. In the case of high percentage of packet loss, most of the models show more than 10% performance improvement. It shows that our TFI can still be effective in zero-shot scenarios.

Result on d_3 in SFDA. As Table XXIX shows, the TFI contribute more to the improvement of the performance of the DL models under IoT attack traffic. In the d_3 scenario, the models obtained an improvement of about 7% in accuracy and f1 score. The advanced models, such as TST and FS-Net, have less performance improvement. We consider TST to be a Transformer-based classification model and its training pattern learns a portion of the mask knowledge. Therefore, in the prediction stage of missing samples, its performance degradation, although also more serious, is slightly lower compared to other models. FS-Net is based on bi-directional GRU, which is more prominent in sequence position focus compared to uni-directional GRU. However, our TFI can still

TABLE XI
RESULTS OF SIMULATED SCENARIO d_4 WITH PACKET LOSS.

Model	Normal		Loss 10%		Loss 20%		Loss 30%	
	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	83.47%	83.08%	60.09%(23.38%↓)	58.79%(24.29%↓)	52.23%(31.24%↓)	50.06%(33.02%↓)	41.66%(41.81%↓)	36.29%(46.79%↓)
LSTM	83.21%	81.96%	51.69%(31.52%↓)	49.99%(32.06%↓)	48.05%(35.16%↓)	44.37%(37.59%↓)	40.00%(43.21%↓)	37.94%(44.02%↓)
GRU	83.33%	82.62%	50.87%(32.46%↓)	49.00%(33.62%↓)	45.62%(37.71%↓)	44.46%(38.16%↓)	38.75%(44.58%↓)	35.22%(47.40%↓)
TST	83.68%	83.24%	65.28%(18.40%↓)	61.08%(22.16%↓)	56.07%(27.61%↓)	51.22%(32.02%↓)	44.75%(38.93%↓)	42.34%(40.90%↓)
SDAE	66.12%	55.63%	53.83%(12.29%↓)	44.19%(11.44%↓)	47.59%(18.53%↓)	38.65%(16.98%↓)	43.73%(22.39%↓)	35.19%(20.44%↓)
FS-Net	82.02%	84.79%	76.19%(5.83%↓)	78.22%(6.57%↓)	66.59%(15.43%↓)	70.29%(14.50%↓)	59.72%(22.30%↓)	62.49%(22.30%↓)
Average	80.31%	78.55%	59.66%(20.65%↓)	56.86%(21.69%↓)	52.69%(27.61%↓)	49.84%(28.71%↓)	44.77%(35.54%↓)	41.58%(36.98%↓)

TABLE XII
RESULTS WITH REAL-WORD SCENARIO d_1 WITH PACKET LOSS.

Model	Normal		Loss 10%		Loss 20%		Loss 30%	
	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	90.60%	90.62%	52.63%(37.97%↓)	49.78%(40.84%↓)	41.85%(48.75%↓)	40.55%(50.07%↓)	39.16%(51.44%↓)	38.83%(51.79%↓)
LSTM	90.53%	90.53%	53.14%(37.39%↓)	49.00%(41.53%↓)	51.34%(39.19%↓)	46.27%(44.26%↓)	50.33%(40.20%↓)	45.41%(45.12%↓)
GRU	87.83%	87.77%	51.23%(36.60%↓)	48.82%(38.95%↓)	45.47%(42.36%↓)	44.00%(43.77%↓)	44.15%(43.68%↓)	43.15%(44.62%↓)
TST	94.16%	94.13%	58.47%(35.69%↓)	52.06%(42.07%↓)	53.28%(40.88%↓)	47.62%(46.51%↓)	48.69%(45.47%↓)	43.01%(51.12%↓)
SDAE	69.37%	62.16%	56.45%(12.92%↓)	48.14%(14.02%↓)	55.68%(13.69%↓)	45.69%(16.47%↓)	54.36%(15.01%↓)	44.72%(17.44%↓)
FS-Net	88.83%	87.87%	84.47%(4.36%↓)	82.43%(5.44%↓)	76.88%(11.95%↓)	72.58%(15.29%↓)	65.82%(23.01%↓)	61.09%(26.78%↓)
Average	86.89%	85.51%	86.89%(27.49%↓)	85.51%(30.47%↓)	59.40%(32.81%↓)	55.04%(36.06%↓)	54.08%(36.47%↓)	49.45%(39.47%↓)

TABLE XIII
RESULTS WITH REAL-WORD SCENARIO d_3 WITH PACKET LOSS.

Model	Normal		Loss 10%		Loss 20%		Loss 30%	
	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	83.36%	82.75%	52.01%(31.35%↓)	51.91%(30.84%↓)	41.33%(42.03%↓)	40.46%(42.29%↓)	38.58%(44.78%↓)	36.88%(45.87%↓)
LSTM	83.37%	83.05%	46.61%(36.76%↓)	44.91%(38.14%↓)	35.78%(47.59%↓)	32.58%(50.47%↓)	38.56%(44.81%↓)	35.48%(47.57%↓)
GRU	83.21%	82.58%	45.59%(37.62%↓)	44.27%(38.31%↓)	37.55%(45.66%↓)	36.06%(46.52%↓)	35.53%(47.68%↓)	34.41%(48.17%↓)
TST	83.59%	83.15%	57.42%(26.17%↓)	53.62%(29.53%↓)	45.28%(38.31%↓)	43.31%(39.84%↓)	43.11%(40.48%↓)	39.09%(44.06%↓)
SDAE	67.29%	60.48%	47.16%(20.13%↓)	44.77%(15.71%↓)	36.27%(31.02%↓)	29.73%(30.75%↓)	35.28%(32.01%↓)	30.45%(30.03%↓)
FS-Net	82.64%	84.32%	73.03%(9.61%↓)	75.77%(8.55%↓)	64.07%(18.57%↓)	66.64%(17.68%↓)	52.71%(29.93%↓)	53.90%(30.42%↓)
Average	80.58%	79.39%	80.58%(26.94%↓)	79.39%(26.85%↓)	53.64%(37.20%↓)	52.54%(37.93%↓)	43.38%(39.95%↓)	41.46%(41.02%↓)

TABLE XIV
RESULTS WITH REAL-WORD SCENARIO d_4 WITH PACKET LOSS.

Model	Normal		Loss 10%		Loss 20%		Loss 30%	
	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	83.49%	82.55%	52.01%(31.48%↓)	50.45%(32.10%↓)	50.45%(33.04%↓)	40.13%(42.42%↓)	40.63%(42.86%↓)	35.91%(46.64%↓)
LSTM	83.26%	82.76%	47.03%(36.23%↓)	45.19%(37.57%↓)	36.99%(46.27%↓)	35.13%(47.63%↓)	38.00%(45.26%↓)	35.43%(47.33%↓)
GRU	83.27%	82.71%	44.82%(38.45%↓)	43.25%(39.46%↓)	38.25%(45.02%↓)	37.07%(45.64%↓)	39.40%(43.87%↓)	36.46%(46.25%↓)
TST	83.69%	83.25%	56.49%(27.20%↓)	53.27%(29.98%↓)	42.73%(40.96%↓)	41.13%(42.12%↓)	41.87%(41.82%↓)	38.07%(45.18%↓)
SDAE	67.95%	60.45%	47.64%(20.31%↓)	42.47%(17.98%↓)	40.50%(27.45%↓)	38.29%(22.16%↓)	40.58%(27.37%↓)	37.37%(23.08%↓)
FS-Net	81.59%	83.99%	70.08%(11.51%↓)	72.61%(11.38%↓)	59.21%(22.38%↓)	60.46%(23.53%↓)	50.95%(30.64%↓)	50.2%(33.79%↓)
Average	80.54%	79.29%	80.54%(27.53%↓)	79.29%(28.08%↓)	53.01%(35.85%↓)	51.21%(37.25%↓)	44.69%(38.63%↓)	42.04%(40.38%↓)

improve the performance of these classification models in the zero-shot case.

Result on d_4 in SFDA. TFI is the most effective in d_4 scenarios for side channel feature imputation, improving the average performance of base deep learning models by 17.98%-25.41% in Accuracy and 18.86%-26.62% in F1 score. The traditional model can be improved by 31.45% accuracy and 33.71% F1 score at 30% packet loss rate. The experimental results demonstrate that our TFI is able to reconstruct a large number of missing side channel features and improve the detection performance of existing models without prior knowledge of the target domain.

APPENDIX D

ADDITIONAL RESULTS OF OTHER FEATURE IMPUTATION METHODS

The classification results are shown in Tables XXXI-XXXIV. In d_1 , on average, the four comparative algorithms

achieved improvements of up to 12.52%, 13.72%, and 11.00% in accuracy for packet loss rates ranging from 10% to 30%, respectively. These results are significantly lower than the enhancements provided by TFI, which increased by 18.02%, 22.63%, and 21.68% for the same loss rates. Similar results were achieved for the d_3 and d_4 scenarios, further demonstrating the effectiveness of our proposed TFI feature imputation model.

The RMSE results across different models under varying packet loss rates are summarized in the Tables XXII. TFI consistently demonstrates superior performance compared to other methods, achieving the lowest RMSE values at all loss rates. Specifically, TFI achieves RMSE values of 0.1524, 0.1668, and 0.1770 for 10%, 20%, and 30% loss rates, respectively, indicating its robustness in handling missing data. In contrast, traditional methods like Markov exhibit higher RMSE values, increasing from 0.2891 at 10% loss to 0.3241 at 30% loss.

TABLE XV
CLASSIFICATION RESULTS OF SIMULATED SCENARIO d_1 WITH IMPUTATION LOSS SIDE-CHANNEL FEATURES.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN+TFI	85.02%(23.40%↑)	84.97%(26.40%↑)	80.49%(26.90%↑)	80.07%(29.33%↑)	77.1%(25.65%↑)	76.24%(25.50%↑)
LSTM+TFI	86.96%(24.85%↑)	86.90%(29.34%↑)	82.32%(29.09%↑)	81.95%(33.66%↑)	78.16%(25.50%↑)	77.30%(30.14%↑)
GRU+TFI	85.4%(25.68%↑)	85.36%(28.43%↑)	80.71%(33.35%↑)	80.48%(34.38%↑)	76.87%(33.35%↑)	76.32%(33.00%↑)
TST+TFI	84.65%(19.74%↑)	84.36%(23.85%↑)	80.86%(22.00%↑)	79.82%(25.86%↑)	74.71%(16.70%↑)	73.10%(21.78%↑)
SDAE+TFI	72.14%(11.78%↑)	65.27%(12.01%↑)	71.51%(16.37%↑)	64.66%(17.57%↑)	70.57%(14.58%↑)	63.74%(17.16%↑)
FS-Net+TFI	90.33%(2.68%↑)	89.29%(3.28%↑)	88.58%(8.06%↑)	87.12%(9.71%↑)	85.75%(14.29%↑)	83.57%(17.45%↑)
Average	84.08%(18.02%↑)	82.69%(20.55%↑)	80.75%(22.63%↑)	79.02%(25.09%↑)	77.19%(21.68%↑)	75.05%(24.17%↑)

TABLE XVI
CLASSIFICATION RESULTS OF SIMULATED SCENARIO d_2 WITH IMPUTATION LOSS SIDE-CHANNEL FEATURES.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN+TFI	99.41%(10.53%↑)	99.41%(10.49%↑)	98.52%(21.19%↑)	98.52%(20.98%↑)	96.88%(32.62%↑)	96.87%(32.25%↑)
LSTM+TFI	97.79%(27.56%↑)	97.79%(28.07%↑)	95.12%(39.52%↑)	95.1%(40.31%↑)	91.68%(46.22%↑)	91.57%(47.09%↑)
GRU+TFI	97.91%(26.75%↑)	97.91%(27.15%↑)	94.98%(38.87%↑)	94.96%(39.72%↑)	91.31%(45.17%↑)	91.20%(46.53%↑)
TST+TFI	99.42%(6.20%↑)	99.42%(6.18%↑)	91.69%(8.88%↑)	91.58%(8.59%↑)	97.19%(25.18%↑)	97.18%(24.75%↑)
SDAE+TFI	95.73%(33.65%↑)	95.73%(34.05%↑)	93.95%(46.70%↑)	93.94%(47.24%↑)	91.07%(52.29%↑)	91.00%(52.78%↑)
FS-Net+TFI	99.87%(4.24%↑)	99.87%(4.21%↑)	99.75%(9.34%↑)	99.75%(9.23%↑)	99.60%(15.94%↑)	99.60%(15.73%↑)
Average	98.36%(18.16%↑)	98.36%(18.36%↑)	95.67%(27.42%↑)	95.64%(27.68%↑)	94.62%(36.24%↑)	94.57%(36.52%↑)

TABLE XVII
CLASSIFICATION RESULTS OF SIMULATED SCENARIO d_3 WITH IMPUTED LOSS SIDE-CHANNEL FEATURES.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN+TFI	81.19%(13.20%↑)	81.20%(13.33%↑)	78.42%(17.27%↑)	78.46%(17.86%↑)	75.57%(19.19%↑)	75.66%(20.39%↑)
LSTM+TFI	88.60%(24.81%↑)	88.62%(25.25%↑)	84.32%(29.45%↑)	84.34%(30.36%↑)	80.11%(31.32%↑)	80.11%(31.78%↑)
GRU+TFI	81.29%(18.99%↑)	81.24%(19.20%↑)	78.40%(24.18%↑)	78.33%(24.36%↑)	75.61%(28.40%↑)	75.52%(28.13%↑)
TST+TFI	91.94%(19.43%↑)	91.95%(19.81%↑)	86.77%(24.17%↑)	86.75%(25.20%↑)	81.58%(24.64%↑)	81.54%(26.27%↑)
SDAE+TFI	73.78%(9.82%↑)	73.57%(10.04%↑)	72.60%(15.68%↑)	72.35%(16.42%↑)	71.19%(20.15%↑)	70.89%(21.17%↑)
FS-Net+TFI	81.05%(3.20%↑)	77.78%(3.47%↑)	80.05%(7.94%↑)	76.63%(8.92%↑)	78.52%(12.46%↑)	74.85%(14.06%↑)
Average	82.98%(14.91%↑)	82.39%(15.18%↑)	80.09%(19.78%↑)	79.48%(20.52%↑)	77.10%(22.69%↑)	76.43%(23.63%↑)

TABLE XVIII
CLASSIFICATION RESULTS OF SIMULATED SCENARIO d_4 WITH IMPUTED LOSS SIDE-CHANNEL FEATURES.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN+TFI	82.32%(22.23%↑)	81.30%(22.51%↑)	80.52%(28.29%↑)	80.07%(30.01%↑)	78.99%(37.33%↑)	78.37%(42.08%↑)
LSTM+TFI	82.15%(30.46%↑)	80.90%(31.00%↑)	80.65%(32.60%↑)	79.34%(34.97%↑)	79.26%(39.26%↑)	77.67%(39.73%↑)
GRU+TFI	81.69%(30.82%↑)	80.97%(31.97%↑)	79.80%(34.18%↑)	79.04%(34.58%↑)	78.18%(39.43%↑)	77.20%(41.98%↑)
TST+TFI	82.99%(17.71%↑)	82.54%(21.46%↑)	81.54%(25.47%↑)	81.04%(29.82%↑)	80.09%(35.34%↑)	79.40%(37.06%↑)
SDAE+TFI	65.61%(11.78%↑)	55.13%(10.94%↑)	65.17%(17.58%↑)	54.68%(16.03%↑)	64.29%(20.56%↑)	54.13%(18.94%↑)
FS-Net+TFI	81.54%(5.35%↑)	84.21%(5.99%↑)	81.00%(14.41%↑)	83.53%(13.24%↑)	80.11%(20.39%↑)	82.38%(19.89%↑)
Average	79.38%(19.73%↑)	77.51%(20.65%↑)	78.11%(25.42%↑)	76.28%(26.44%↑)	76.82%(32.05%↑)	74.86%(33.28%↑)

Pre-trained language models, including BERT, Roberta, and Deberta, also show higher RMSE values compared to TFI. For example, BERT and Roberta remain above 0.87 across all loss rates, with minimal differences between the two. Deberta performs better among the pre-trained models, with RMSE values of 0.4401, 0.4393, and 0.4325 at 10%, 20%, and 30% loss rates, respectively, though still significantly higher than TFI. These results highlight the effectiveness of TFI in accurately reconstructing traffic features under various levels of packet loss, outperforming both traditional approaches and advanced pre-trained language models.

APPENDIX E ADDITIONAL RESULTS OF TFM MODULE

The other classification results are shown in Table XXXV.

APPENDIX F ANALYSIS OF DIFFERENT SEQUENCE LENGTHS

To assess the applicability of the Nüwa framework, experiments were conducted on sequence lengths of 256 and 1024. Our experimental setup for both lengths follows the configuration in Section V-A, padding insufficient sequences with zeros. Results are presented in Fig. 17 and Section F of [17]. The findings indicate that our method is effective across different sequence lengths. At a length of 256, improvements of 18.19%, 28.47%, and 35.79% are noted at packet loss

TABLE XIX
CLASSIFICATION RESULTS OF REAL-WORD SCENARIO d_1 WITH IMPUTATION LOSS SIDE-CHANNEL FEATURES.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN+TFI	89.93%(37.30%↑)	89.94%(40.16%↑)	80.89%(48.08%↑)	80.37%(49.39%↑)	72.90%(50.77%↑)	71.52%(51.11%↑)
LSTM+TFI	88.83%(35.69%↑)	87.87%(38.87%↑)	82.76%(37.49%↑)	82.77%(41.60%↑)	74.03%(38.50%↑)	72.94%(42.46%↑)
GRU+TFI	85.14%(33.91%↑)	83.18%(34.36%↑)	81.19%(39.67%↑)	80.95%(39.18%↑)	73.40%(40.99%↑)	72.29%(40.03%↑)
TST+TFI	88.05%(29.58%↑)	86.52%(34.46%↑)	81.60%(34.77%↑)	81.17%(38.90%↑)	69.31%(39.36%↑)	66.08%(43.51%↑)
SDAE+TFI	68.53%(12.08%↑)	61.27%(13.13%↑)	66.48%(12.85%↑)	58.98%(15.58%↑)	64.13%(14.17%↑)	56.60%(16.55%↑)
FS-Net+TFI	86.46%(1.99%↑)	84.98%(2.55%↑)	81.87%(9.58%↑)	79.68%(12.40%↑)	76.60%(20.64%↑)	73.53%(23.89%↑)
Average	84.49%(25.09%↑)	82.29%(27.25%↑)	79.13%(30.41%↑)	77.32%(32.84%↑)	71.73%(34.07%↑)	68.83%(36.25%↑)

TABLE XX
CLASSIFICATION RESULTS OF REAL-WORD SCENARIO d_3 WITH IMPUTATION LOSS SIDE-CHANNEL FEATURES.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN+TFI	80.92%(28.91%↑)	80.19%(28.28%↑)	77.85%(39.59%↑)	76.77%(39.73%↑)	74.61%(42.34%↑)	72.75%(43.31%↑)
LSTM+TFI	81.23%(34.62%↑)	80.81%(35.90%↑)	78.70%(45.45%↑)	78.02%(48.23%↑)	75.06%(42.67%↑)	73.75%(45.33%↑)
GRU+TFI	80.27%(34.68%↑)	79.52%(35.25%↑)	77.71%(42.72%↑)	76.64%(43.46%↑)	74.23%(44.74%↑)	72.38%(45.11%↑)
TST+TFI	81.65%(24.23%↑)	81.12%(27.50%↑)	78.59%(36.37%↑)	77.72%(37.81%↑)	74.22%(38.54%↑)	72.67%(42.03%↑)
SDAE+TFI	66.43%(19.27%↑)	59.58%(14.81%↑)	65.44%(30.16%↑)	58.58%(29.85%↑)	64.31%(31.15%↑)	57.42%(29.13%↑)
FS-Net+TFI	81.47%(8.44%↑)	82.89%(7.12%↑)	80.10%(17.40%↑)	81.04%(16.25%↑)	77.44%(28.76%↑)	77.35%(28.99%↑)
Average	78.66%(25.02%↑)	77.35%(24.81%↑)	76.40%(35.28%↑)	74.80%(35.89%↑)	73.31%(38.03%↑)	71.05%(38.98%↑)

TABLE XXI
CLASSIFICATION RESULTS OF REAL-WORD SCENARIO d_4 WITH IMPUTATION LOSS SIDE-CHANNEL FEATURES.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN	80.91%(28.90%↑)	79.86%(29.41%↑)	77.89%(30.46%↑)	76.43%(39.73%↑)	74.68%(40.28%↑)	72.51%(43.95%↑)
LSTM	81.05%(34.02%↑)	80.45%(35.26%↑)	78.55%(44.06%↑)	77.56%(45.32%↑)	74.98%(43.05%↑)	73.26%(45.02%↑)
GRU	80.22%(35.40%↑)	79.54%(36.29%↑)	77.78%(41.97%↑)	76.68%(42.47%↑)	74.14%(40.82%↑)	72.16%(43.08%↑)
TST	81.87%(25.38%↑)	81.34%(28.07%↑)	79.39%(39.14%↑)	78.56%(40.21%↑)	75.28%(40.00%↑)	73.71%(43.27%↑)
SDAE	66.89%(19.25%↑)	59.34%(16.87%↑)	65.85%(26.39%↑)	58.11%(21.05%↑)	63.87%(26.31%↑)	55.92%(21.97%↑)
FS-Net	80.47%(10.39%↑)	82.63%(10.02%↑)	79.43%(21.26%↑)	80.89%(22.17%↑)	76.90%(29.52%↑)	77.26%(32.43%↑)
Average	78.57%(25.56%↑)	77.19%(25.98%↑)	76.48%(33.88%↑)	74.71%(35.15%↑)	73.31%(36.66%↑)	70.80%(38.28%↑)

TABLE XXII
RMSE RESULTS ON DIFFERENT FEATURE IMPUTATION MODELS IN SIMULATED NETWORK.

RMSE	Imputed 10%	Imputed 20%	Imputed 30%
TFI	0.1524	0.1668	0.1770
Markov	0.2891	0.3135	0.3241
BERT	0.9232	0.9273	0.9278
Roberta	0.8726	0.8771	0.8778
Deberta	0.4401	0.4393	0.4325

rates of 10%~30%, respectively. With TFI, the six DL models nearly match the performance of no packet loss scenarios. At length 1024, the enhancement mirrors that of lengths 256 and 512.

The results of sequence length 256 and 1024 are shown in Tables XXXVI, XXXVII, XXXVIII, XXXIX. Additionally, our model demonstrates superior reconstruction results across various sequence lengths, emphasizing its robust applicability.

APPENDIX G ANALYSIS OF VARIOUS MASK RATIO

To explore the impact of varying mask ratios on the original sequences during the TFI's pre-training phase, we conducted

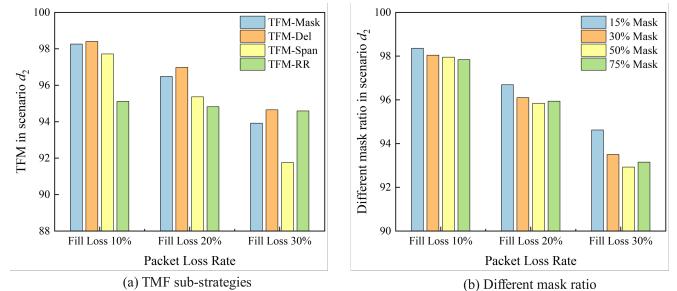


Fig. 16. Average accuracy of TFM sub-strategies and different mask ratio of input sequences on d_2 .

four sets of ablation experiments with mask ratios set at 15%, 30%, 50%, and 75%. Taking the d_2 scenario as an example, as shown in the Table XXI, XXII, XXIII, XXIV and Fig. 16 (b), when the mask ratio is set to 15%, TFI achieves an average accuracy of 99.80% for all missing feature imputation. As the mask ratio increases to 30%, 50%, and 75%, the performance changes are not pronounced. As the packet loss rate rises, the DL model's overall accuracy and F1-score decline slightly, yet the decrease does not exceed 1%. While varying mask ratios have a negligible impact on the final feature imputation outcomes, higher mask ratios necessitate the computation of

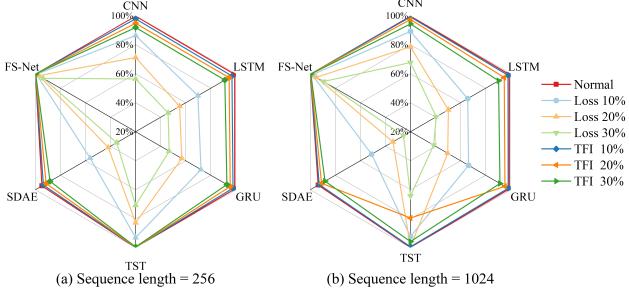


Fig. 17. Classification results with different mask ratio of input sequences.

more parameters during the pre-training phase. Therefore, a sequence mask ratio of 15% is deemed appropriate for the pre-training stage in practical applications. Please refer to Section G of [17] for detailed results.

We conducted four sets of ablation experiments with mask ratios set at 15%, 30%, 50%, and 75%. And the additional experiment results are shown in the Tables XXV, XXVI.

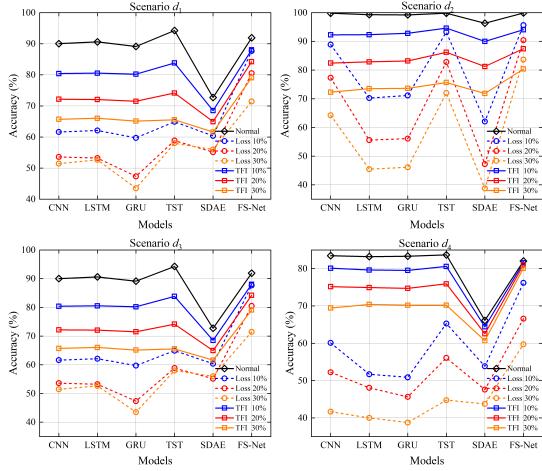


Fig. 18. Classification results of packet with intact, loss and Imputed Loss in SFDA.

TABLE XXIII
CLASSIFICATION RESULTS WITH DIFFERENT MASK RATIO OF INPUT SEQUENCES ON d_1

Packet Loss	Loss 10%							
	15%		30%		50%		75%	
Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	85.02%	84.97%	85.19%	85.14%	85.41%	85.37%	84.41%	84.34%
LSTM	86.96%	86.90%	86.88%	86.82%	86.75%	86.69%	86.23%	86.15%
GRU	85.40%	85.36%	85.5%	85.46%	85.32%	85.28%	84.92%	84.87%
TST	88.89%	88.73%	88.67%	88.51%	88.53%	88.36%	87.47%	87.24%
SDAE	72.14%	65.27%	72.10%	65.24%	71.99%	65.14%	71.84%	65.00%
FS-Net	90.33%	89.29%	90.15%	89.26%	89.82%	88.95%	90.05%	89.13%
Average	84.79%	83.42%	84.75%	83.41%	84.64%	83.30%	84.15%	82.79%
Packet Loss	Loss 20%							
	15%		30%		50%		75%	
Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	80.49%	80.07%	81.02%	80.70%	80.94%	80.55%	80.04%	79.63%
LSTM	82.78%	82.49%	82.31%	81.96%	81.67%	81.28%	82.32%	81.95%
GRU	80.71%	80.48%	81.21%	81.03%	80.90%	80.70%	80.40%	80.16%
TST	83.3%	82.44%	83.69%	82.85%	83.00%	82.19%	81.92%	80.94%
SDAE	71.51%	64.66%	71.57%	64.72%	71.75%	64.90%	71.35%	64.53%
FS-Net	88.58%	87.12%	87.88%	86.68%	88.23%	87.06%	87.76%	86.55%
Average	81.23%	79.54%	81.28%	79.66%	81.08%	79.45%	80.63%	78.96%
Packet Loss	Loss 30%							
	15%		30%		50%		75%	
Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	77.10%	76.24%	77.32%	76.51%	77.14%	76.33%	76.27%	75.41%
LSTM	78.16%	77.30%	79.13%	78.34%	78.49%	77.65%	77.88%	77.01%
GRU	76.87%	76.32%	77.39%	76.90%	77.25%	76.73%	76.66%	76.14%
TST	78.47%	76.78%	79.43%	77.86%	78.38%	76.75%	77.09%	75.23%
SDAE	70.57%	63.74%	70.88%	64.07%	70.73%	63.93%	70.39%	63.61%
FS-Net	85.75%	83.57%	86.23%	84.67%	85.81%	84.09%	85.12%	83.38%
Average	77.82%	75.66%	78.40%	76.39%	77.97%	75.91%	77.24%	75.13%

TABLE XXIV
CLASSIFICATION RESULTS WITH DIFFERENT MASK RATIO OF INPUT SEQUENCES ON d_2

Packet Loss	Loss 10%							
	15%		30%		50%		75%	
Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	99.41%	99.41%	99.03%	99.03%	98.93%	98.93%	98.84%	98.84%
LSTM	97.79%	97.79%	97.52%	97.52%	97.35%	97.35%	97.40%	97.40%
GRU	97.91%	97.91%	97.61%	97.61%	97.49%	97.49%	97.34%	97.35%
TST	99.42%	99.42%	99.08%	99.08%	98.98%	98.98%	98.90%	98.90%
SDAE	95.73%	95.73%	95.26%	95.26%	95.14%	95.15%	95.02%	95.03%
FS-Net	99.87%	99.87%	99.72%	99.72%	99.79%	99.79%	99.53%	99.54%
Average	98.36%	98.36%	98.04%	98.04%	97.95%	97.95%	97.84%	97.84%
Packet Loss	Loss 20%							
	15%		30%		50%		75%	
Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	98.52%	98.52%	97.84%	97.84%	97.37%	97.37%	97.25%	97.25%
LSTM	94.24%	94.23%	93.76%	93.74%	94.02%	94.01%	95.12%	95.10%
GRU	94.98%	94.96%	94.26%	94.25%	93.65%	93.64%	93.75%	93.74%
TST	98.71%	98.71%	98.01%	98.01%	97.66%	97.67%	97.55%	97.55%
SDAE	93.95%	93.94%	93.23%	93.23%	92.77%	92.77%	92.75%	92.76%
FS-Net	99.75%	99.75%	99.51%	99.52%	99.59%	99.60%	99.22%	99.24%
Average	96.69%	96.69%	96.10%	96.10%	95.84%	95.84%	95.94%	95.94%
Packet Loss	Loss 30%							
	15%		30%		50%		75%	
Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	96.88%	96.87%	95.66%	95.66%	95.02%	95.02%	95.10%	95.10%
LSTM	91.68%	91.57%	90.08%	89.99%	89.24%	89.14%	90.06%	90.03%
GRU	91.31%	91.20%	90.15%	90.07%	89.36%	89.27%	90.00%	89.95%
TST	97.18%	97.17%	95.89%	95.89%	95.31%	95.30%	95.33%	95.33%
SDAE	91.07%	91.00%	90.01%	89.96%	89.42%	89.38%	89.64%	89.62%
FS-Net	99.60%	99.60%	99.21%	99.23%	99.17%	99.19%	98.76%	98.79%
Average	94.62%	94.57%	93.50%	93.47%	92.92%	92.88%	93.15%	93.14%

APPENDIX H ADDITIONAL RESULTS OF PERFORMANCE ANALYSIS OF NÜWA

The results of average performance variation are shown in Table XL.

TABLE XXV
CLASSIFICATION RESULTS WITH DIFFERENT MASK RATIO OF INPUT SEQUENCES ON d_3 .

Packet Loss	Loss 10%								
	15%		30%		50%		75%		
Mask Ratio	Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	81.19%	81.20%	81.27%	81.27%	80.96%	80.98%	80.45%	80.50%	
LSTM	88.60%	88.62%	88.75%	88.77%	88.48%	88.50%	87.67%	87.71%	
GRU	81.29%	81.24%	81.39%	81.33%	81.18%	81.13%	80.57%	80.53%	
TST	91.95%	91.96%	92.24%	92.24%	91.77%	91.77%	90.73%	90.73%	
SDAE	73.78%	73.57%	73.76%	73.54%	73.65%	73.42%	73.46%	73.22%	
FS-Net	81.05%	77.78%	81.45%	78.24%	81.18%	77.07%	81.08%	77.81%	
Average	82.98%	82.40%	83.14%	82.57%	82.87%	82.15%	82.33%	81.75%	
Packet Loss	Loss 20%								
	15%		30%		50%		75%		
Mask Ratio	Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	78.42%	78.46%	78.51%	78.55%	78.09%	78.15%	77.11%	77.19%	
LSTM	84.32%	84.34%	84.70%	84.72%	84.46%	84.48%	82.97%	82.99%	
GRU	78.65%	78.65%	78.25%	78.18%	77.51%	77.46%	78.40%	78.33%	
TST	86.81%	86.78%	87.38%	87.36%	86.60%	86.57%	84.97%	84.93%	
SDAE	72.60%	72.35%	72.61%	72.35%	72.46%	72.19%	72.18%	71.91%	
FS-Net	80.05%	76.63%	80.55%	77.16%	80.47%	77.07%	80.09%	76.64%	
Average	80.14%	79.54%	80.33%	79.72%	79.93%	79.32%	79.29%	78.67%	
Packet Loss	Loss 30%								
	15%		30%		50%		75%		
Mask Ratio	Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	75.57%	75.66%	76.25%	76.32%	75.68%	75.77%	74.61%	74.74%	
LSTM	80.11%	80.11%	80.69%	80.72%	80.40%	80.42%	79.07%	79.08%	
GRU	75.61%	75.52%	76.04%	75.96%	75.85%	75.75%	74.83%	74.76%	
TST	81.49%	81.42%	82.41%	82.35%	81.87%	81.82%	80.06%	79.98%	
SDAE	71.19%	70.89%	71.57%	71.29%	71.49%	71.20%	71.02%	70.73%	
FS-Net	78.52%	74.85%	79.37%	75.81%	78.94%	75.32%	78.74%	75.08%	
Average	77.08%	76.41%	77.72%	77.08%	77.37%	76.71%	76.39%	75.73%	

TABLE XXVI
CLASSIFICATION RESULTS WITH DIFFERENT MASK RATIO OF INPUT SEQUENCES ON d_4 .

Packet Loss	Loss 10%								
	15%		30%		50%		75%		
Mask Ratio	Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	82.32%	81.93%	82.84%	82.46%	82.21%	81.82%	82.07%	81.64%	
LSTM	82.15%	80.90%	82.76%	81.51%	82.14%	80.85%	82.05%	80.67%	
GRU	81.69%	80.97%	82.58%	81.86%	81.75%	81.02%	81.58%	80.80%	
TST	82.94%	82.48%	83.33%	82.87%	82.88%	82.41%	82.77%	82.25%	
SDAE	65.61%	55.13%	65.94%	55.45%	65.69%	55.21%	65.68%	55.19%	
FS-Net	90.33%	89.29%	81.58%	83.58%	81.56%	83.53%	81.56%	83.46%	
Average	80.84%	78.45%	79.84%	77.96%	79.37%	77.47%	79.29%	77.34%	
Packet Loss	Loss 20%								
	15%		30%		50%		75%		
Mask Ratio	Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	80.52%	80.07%	82.04%	81.62%	80.60%	80.14%	80.52%	80.02%	
LSTM	80.65%	79.34%	81.92%	80.62%	80.88%	79.48%	80.70%	79.17%	
GRU	79.80%	79.04%	81.43%	80.67%	79.96%	79.15%	79.72%	78.84%	
TST	81.50%	80.99%	82.66%	82.15%	81.60%	81.04%	81.32%	80.69%	
SDAE	65.17%	54.68%	65.75%	55.26%	65.27%	54.76%	65.24%	54.74%	
FS-Net	88.58%	87.12%	80.99%	82.90%	80.99%	82.76%	80.71%	82.40%	
Average	79.37%	76.87%	79.13%	77.20%	78.22%	76.22%	78.04%	75.98%	
Packet Loss	Loss 30%								
	15%		30%		50%		75%		
Mask Ratio	Model	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	78.99%	78.37%	81.08%	80.47%	79.19%	78.57%	79.15%	78.51%	
LSTM	79.34%	77.67%	81.08%	79.49%	79.54%	77.89%	79.41%	77.63%	
GRU	78.18%	77.20%	80.27%	79.27%	78.47%	77.48%	78.36%	77.32%	
TST	80.04%	79.34%	81.88%	81.15%	80.35%	79.65%	79.97%	79.20%	
SDAE	64.62%	54.13%	65.35%	54.85%	64.80%	54.28%	64.80%	54.28%	
FS-Net	85.75%	83.57%	80.53%	82.21%	80.28%	81.78%	80.13%	81.63%	
Average	77.82%	75.05%	78.37%	76.24%	77.11%	74.94%	76.97%	74.76%	

TABLE XXVII
RESULTS ON CLASSIFYING SCENARIO d_1 FLOWS WITH IMPUTED LOSS PACKETS IN SFDA.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN	80.40%(18.78%↑)	80.22%(21.65%↑)	72.16%(18.57%↑)	70.91%(20.17%↑)	65.71%(14.26%↑)	63.56%(12.82%↑)
LSTM	80.55%(18.44%↑)	80.36%(22.8%↑)	72.07%(18.84%↑)	71.34%(23.05%↑)	66.04%(13.38%↑)	64.68%(17.52%↑)
GRU	80.22%(20.50%↑)	80.17%(23.24%↑)	71.51%(24.15%↑)	71.01%(24.91%↑)	65.14%(21.62%↑)	64.24%(20.92%↑)
TST	83.83%(18.92%↑)	83.57%(23.06%↑)	74.16%(15.30%↑)	71.74%(17.78%↑)	65.54%(7.53%↑)	61.55%(10.23%↑)
SDAE	68.50%(8.14%↑)	61.75%(8.49%↑)	64.95%(9.81%↑)	58.35%(11.26%↑)	61.62%(5.63%↑)	55.25%(8.67%↑)
FS-Net	88.06%(0.41%↑)	86.53%(0.52%↑)	84.23%(3.71%↑)	81.77%(4.36%↑)	79.09%(7.63%↑)	74.94%(8.82%↑)
Average	80.26%(14.20%↑)	78.77%(16.63%↑)	73.18%(15.06%↑)	70.85%(16.92%↑)	67.19%(11.68%↑)	64.04%(13.16%↑)

TABLE XXVIII
RESULTS ON CLASSIFYING REAL FLOWS OF SFDA IN SCENARIO d_2 .

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN+TFI	92.27%(3.39%↑)	92.33%(3.41%↑)	82.44%(5.11%↑)	82.65%(5.11%↑)	72.29%(8.03%↑)	72.52%(7.90%↑)
LSTM+TFI	92.32%(22.09%↑)	92.33%(22.61%↑)	82.86%(27.26%↑)	82.78%(27.99%↑)	73.53%(28.07%↑)	73.29%(28.81%↑)
GRU+TFI	92.81%(21.65%↑)	92.84%(22.08%↑)	83.18%(27.07%↑)	83.2%(27.96%↑)	73.63%(27.49%↑)	73.55%(28.88%↑)
TST+TFI	94.61%(1.39%↑)	94.65%(1.41%↑)	86.19%(3.38%↑)	86.42%(3.43%↑)	75.66%(3.65%↑)	76.12%(3.69%↑)
SDAE+TFI	89.98%(27.90%↑)	90.00%(28.32%↑)	81.25%(34.00%↑)	81.29%(34.59%↑)	71.83%(33.05%↑)	71.84%(33.62%↑)
FS-Net+TFI	94.05%(1.58%↑)	94.18%(1.47%↑)	87.42%(2.98%↑)	87.81%(2.70%↑)	80.38%(3.28%↑)	81.00%(2.87%↑)
Average	92.67%(12.47%↑)	92.72%(12.73%↑)	83.89%(15.64%↑)	84.03%(16.06%↑)	74.55%(16.17%↑)	74.72%(16.67%↑)

TABLE XXIX
CLASSIFYING RESULTS ON SCENARIO d_3 FLOWS WITH IMPUTED LOSS PACKETS IN SFDA.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN	73.79%(5.80%↑)	73.76%(5.89%↑)	65.92%(4.77%↑)	65.44%(4.84%↑)	59.80%(3.42%↑)	58.72%(3.45%↑)
LSTM	79.23%(15.44%↑)	79.12%(15.75%↑)	67.72%(12.85%↑)	66.94%(12.96%↑)	59.55%(10.76%↑)	57.78%(9.45%↑)
GRU	74.27%(11.97%↑)	74.08%(12.04%↑)	65.52%(11.30%↑)	64.99%(11.02%↑)	59.36%(12.15%↑)	58.30%(10.91%↑)
TST	78.61%(6.10%↑)	78.25%(6.11%↑)	66.47%(3.87%↑)	64.98%(3.43%↑)	58.68%(1.74%↑)	56.08%(0.81%↑)
SDAE	69.89%(5.93%↑)	69.55%(6.02%↑)	64.70%(7.78%↑)	64.01%(8.08%↑)	60.21%(9.17%↑)	58.98%(9.26%↑)
FS-Net	78.38%(0.54%↑)	74.97%(0.66%↑)	73.49%(1.38%↑)	69.65%(1.94%↑)	67.89%(1.83%↑)	63.84%(3.05%↑)
Average	75.70%(7.63%↑)	74.96%(7.74%↑)	67.30%(6.99%↑)	66.00%(7.05%↑)	60.92%(6.51%↑)	58.95%(6.16%↑)

TABLE XXX
RESULTS ON CLASSIFYING SCENARIO d_4 FLOWS WITH IMPUTED LOSS PACKETS IN SFDA.

Model	Imputed Loss 10%		Imputed Loss 20%		Imputed Loss 30%	
	Acc	F1	Acc	F1	Acc	F1
CNN	80.11%(20.02%↑)	79.65%(20.86%↑)	75.17%(22.94%↑)	74.73%(24.67%↑)	69.45%(27.79%↑)	69.26%(32.97%↑)
LSTM	79.64%(27.95%↑)	78.07%(28.17%↑)	74.93%(26.88%↑)	73.19%(28.82%↑)	70.41%(30.41%↑)	68.88%(30.94%↑)
GRU	79.54%(28.67%↑)	78.55%(29.55%↑)	74.72%(29.10%↑)	73.44%(28.98%↑)	70.20%(31.45%↑)	68.93%(33.71%↑)
TST	80.59%(15.31%↑)	79.92%(18.84%↑)	75.92%(19.85%↑)	75.02%(23.80%↑)	70.20%(25.45%↑)	69.41%(27.07%↑)
SDAE	64.41%(10.58%↑)	53.93%(9.74%↑)	62.56%(14.97%↑)	52.14%(13.49%↑)	60.69%(16.96%↑)	50.35%(15.16%↑)
FS-Net	81.54%(5.35%↑)	84.21%(5.99%↑)	81.00%(14.41%↑)	83.53%(13.24%↑)	80.11%(20.39%↑)	82.38%(19.89%↑)
Average	77.64%(17.98%↑)	75.72%(18.86%↑)	74.05%(21.36%↑)	72.01%(22.17%↑)	70.18%(25.41%↑)	68.20%(26.62%↑)

TABLE XXXI
CLASSIFICATION ACCURACY WITH DIFFERENT FEATURE IMPUTATION METHODS IN d_1 .

Model	Packet Loss 10%				Packet Loss 20%				Packet Loss 30%			
	ZeroPad		Markov		BERT		Roberta		Deberta		ZeroPad	
Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc
CNN	77.91%(16.29%↑)	77.49%(18.83%↑)	45.39%(16.23%↓)	43.8%(14.77%↓)	73.75%(12.13%↑)	73.75%(15.18%↑)	77.25%(15.63%↑)	76.71%(18.14%↑)	77.25%(15.63%↑)	76.71%(18.14%↑)	68.87%(15.63%↑)	68.88%(30.94%↑)
LSTM	79.10%(16.99%↑)	78.76%(21.21%↑)	45.00%(17.11%↓)	43.76%(13.80%↓)	78.79%(16.68%↑)	78.41%(20.85%↑)	78.79%(16.68%↑)	78.41%(20.85%↑)	78.79%(16.68%↑)	78.41%(20.85%↑)	78.41%(20.85%↑)	78.41%(20.85%↑)
GRU	79.54%(28.67%↑)	78.55%(29.55%↑)	43.34%(16.38%↓)	42.83%(14.10%↓)	78.43%(18.71%↑)	78.26%(21.33%↑)	78.43%(18.71%↑)	78.26%(21.33%↑)	78.43%(18.71%↑)	78.26%(21.33%↑)	78.43%(18.71%↑)	78.43%(20.30%↑)
TST	78.07%(13.16%↑)	77.29%(16.69%↑)	45.42%(19.49%↓)	42.47%(18.04%↓)	77.66%(12.75%↑)	76.65%(16.14%↑)	77.66%(12.75%↑)	76.65%(16.14%↑)	77.66%(12.75%↑)	77.66%(16.14%↑)	77.66%(16.14%↑)	77.66%(16.14%↑)
SDAE	68.47%(8.11%↑)	61.5%(8.24%↑)	51.99%(8.37%↓)	44.46%(8.80%↓)	68.44%(8.08%↑)	61.46%(8.20%↑)	68.44%(8.08%↑)	61.46%(8.20%↑)	68.44%(8.08%↑)	61.46%(8.20%↑)	68.44%(8.08%↑)	61.46%(8.20%↑)
FS-Net	89.35%(1.69%↑)	86.01%(0%↑)	42.47%(45.18%↓)	33.33%(52.68%↓)	87.21%(0.44%↓)	85.79%(0.31%↓)	87.27%(0.38%↓)	85.81%(0.20%↓)	87.21%(0.44%↓)	85.79%(0.20%↓)	87.21%(0.44%↓)	85.79%(0.20%↓)
Average	78.58%(12.52%↑)	76.56%(14.42%↑)	41.78%(20.37%↑)	74.84%(8.78%↑)	74.83%(12.69%↑)	77.97%(11.91%↑)	76.22%(14.08%↑)	77.96%(11.9↑)	76.22%(14.08%↑)	77.96%(11.9↑)	76.22%(14.08%↑)	76.22%(14.08%↑)
Model	Packet Loss 20%				BERT				Roberta			
	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	69.69%(16.10%↑)	67.82%(17.08%↑)	47.04%(6.55%↓)	44.27%(6.47%↓)	64.97%(11.38%↑)	64.69%(13.95%↑)	68.87%(15.28%↑)	66.94%(16.20%↑)	68.87%(15.28%↑)	66.94%(16.20%↑)	68.87%(15.28%↑)	68.87%(15.28%↑)
LSTM	70.55%(17.32%↑)	69.39%(21.10%↑)	46.06%(7.17%↓)	44.13%(4.16%↓)	68.41%(15.18%↑)	67.99%(19.70%↑)	70.41%(17.18%↑)	69.20%(20.91%↑)	70.41%(17.18%↑)	69.20%(20.91%↑)	70.41%(17.18%↑)	70.41%(17.18%↑)
GRU	70.21%(22.85%↑)	69.56%(23.46%↑)	43.82%(3.54%↓)	42.98%(3.12%↓)	67.3%(19.94%↑)	67.07%(20.97%↑)	69.9%(22.54%↑)	69.10%(23.00%↑)	69.9%(22.54%↑)	69.9%(22.54%↑)	69.9%(22.54%↑)	69.9%(22.54%↑)
TST	70.18%(11.32%↑)	66.72%(12.76%↑)	48.73%(10.13%↓)	42.95%(11.01%↓)	67.55%(8.69%↑)	67.22%(13.26%↑)	70.95%(12.09%↑)	67.24%(13.28%↑)	70.95%(12.09%↑)	67.24%(13.28%↑)	70.95%(12.09%↑)	70.95%(12.09%↑)
SDAE	65.20%(10.06%↑)	57.78%(10.69%↑)	52.04%(3.10%↓)	44.10%(2.99%↓)	62.99%(7.85%↑)	62.84%(15.75%↑)	65.1%(9.96%↑)	57.66%(10.57%↑)	65.1%(9.96%↑)	57.66%(10.57%↑)	65.1%(9.96%↑)	57.66%(10.57%↑)
FS-Net	85.20%(4.68%↑)	83.25%(5.84%↑)	43.37%(37.15%↓)	33.64%(43.77%↓)	78.31%(2.21%↑)	77.92%(0.51%↑)	80.28%(0.24%↑)	78.09%(0.68%↑)	80.51%(0.01%↑)	78.09%(0.68%↑)	80.51%(0.01%↑)	78.39%(0.98%↑)
Average	71.84%(13.72%↑)	69.09%(15.16%↑)	46.84%(11.27%↓)	42.01%(11.92%↓)	68.26%(10.14%↑)	67.96%(14.02%↑)	70.92%(0.92%↑)	68.04%(1.05%↓)	70.96%(12.84%↑)	68.09%(14.16%↑)	68.09%(14.16%↑)	68.09%(14.16%↑)
Model	Packet Loss 30%				BERT				Roberta			
	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1
CNN	64.40%(12.95%↑)	61.54%(10.80%↑)	49.55%(1.90%↑)	45.59%(5.15%↑)	60.37%(8.92%↑)	60.55%(9.81%↓)	63.47%(12.02%↑)	60.51%(9.77%↑)	63.47%(12.02%↑)	60.51%(9.77%↑)	63.47%(12.02%↑)	60.51%(9.77%↑)
LSTM	65.95%(13.29%↑)	64.06%(16.90%↑)	46.11%(6.55%↑)	43.78%(3.38%↑)	61.48%(8.82%↑)	61.81%(14.65%↑)	65.19%(12.53%↑)	63.2%(16.04%↑)	65.19%(12.53%↑)	63.2%(16.04%↑)	65.19%(12.53%↑)	63.2%(16.04%↑)
GRU	64.61%(21.09%↑)	63.48%(20.16%↑)	44.43%(0.91%↓)	43.45%(0.13%↓)	60.89%(17.37%↑)	61.27%(17.95%↑)	64.10%(20.58%↑)	62.81%(19.49%↑)	64.10%(20.58%↑)	62.81%(19.49%↑)	64.10%(20.58%↑)	62.81%(19.49%↑)
TST	60.94%(2.93%↑)	56.31%(4.99%↑)	49.31%(8.70%↑)	41.65%(9.67%↑)	55.94%(2.07%↑)	55.62%(4.30%↑)	59.84%(1.83%↑)	53.71%(2.39%↑)	59.84%(1.83%↑)	53.71%(2.39%↑)	59.84%(1.83%↑)	53.71%(2.39%↑)
SDAE	63.14%(7.15%↑)	55.11%(8.53%↑)	52.84%(3.15%↑)	44.02%(2.56%↑)	59.51%(3.52%↓)	59.51%(12.93%↓)	63.21%(7.22%↑)	55.16%(8.58%↑)	63.21%(7.22%↑)	55.16%(8.58%↑)	63.21%(7.22%↑)	55.16%(8.58%↑)
FS-Net	80.02%(8.56%↑)	76.76%(10.64%↑)	44.22%(27.24%↑)	33.98%(32.14%↑)	66.91%(4.55%↑)	66.76%(0.64%↑)	70.97%(0.49%↑)	68.41%(2.29%↑)	70.97%(0.49%↑)	68.41%(2.29%↑)	70.97%(0.49%↑)	68.41%(2.29%↑)
Average	66.51%(11.00%↑)	62.88%(12.00%↑)	47.74%(7.77%↓)	42.08%(8.80%↓)	60.85%(5.34%↑)	60.92%(10.05%↑)	64.46%(8.95%↑)	60.63%(9.76%↑)	64.36%(8.84%↑)	60.5(9.63%↑)	60.5(9.63%↑)	60.5(9.63%↑)

TABLE XXXII
CLASSIFICATION ACCURACY WITH DIFFERENT FEATURE IMPUTATION METHODS IN d_2 .

Model	Packet Loss 10%									
	ZeroPad		Markov		BERT		Roberta		Deberta	
Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	
CNN	96.24% (7.36%) \uparrow	96.22% (7.30%) \uparrow	20.06% (68.82%) \downarrow	20.00% (68.92%) \downarrow	88.12% (0.76%) \downarrow	88.12% (0.76%) \downarrow	96.21% (7.33%) \uparrow	96.2% (7.28%) \uparrow	91.19% (2.31%) \uparrow	91.16% (2.24%) \uparrow
LSTM	93.91% (23.68%) \uparrow	93.89% (24.17%) \uparrow	19.92% (50.31%) \downarrow	19.84% (49.88%) \downarrow	84.27% (14.04%) \uparrow	84.27% (14.55%) \uparrow	90.88% (20.65%) \uparrow	90.82% (21.1%) \uparrow	86.17% (15.94%) \uparrow	86.18% (16.46%) \uparrow
GRU	94.79% (23.63%) \uparrow	94.75% (23.99%) \uparrow	19.96% (51.2%) \downarrow	19.88% (50.88%) \downarrow	83.52% (12.36%) \uparrow	83.52% (12.76%) \uparrow	92.37% (21.21%) \uparrow	92.34% (21.58%) \uparrow	85.82% (14.66%) \uparrow	85.81% (15.05%) \uparrow
TST	96.88% (3.66%) \uparrow	96.85% (3.61%) \uparrow	19.89% (73.33%) \downarrow	19.84% (73.40%) \downarrow	90.79% (2.43%) \uparrow	90.79% (2.45%) \uparrow	96.74% (3.52%) \uparrow	96.71% (3.47%) \uparrow	92.39% (0.83%) \downarrow	92.3% (0.87%) \downarrow
SDAE	89.88% (27.80%) \uparrow	89.94% (28.26%) \uparrow	20.01% (42.07%) \downarrow	19.99% (41.78%) \downarrow	80.72% (18.64%) \uparrow	80.72% (19.04%) \uparrow	88.38% (26.3%) \uparrow	88.44% (26.76%) \uparrow	83.32% (21.24%) \uparrow	83.39% (21.71%) \uparrow
FS-Net	97.83% (2.20%) \uparrow	97.84% (2.18%) \uparrow	19.93% (75.70%) \downarrow	19.85% (75.81%) \downarrow	93.19% (2.44%) \downarrow	93.19% (2.47%) \downarrow	92.14% (3.49%) \downarrow	92.3% (3.36%) \downarrow	95.39% (0.24%) \downarrow	95.48% (0.18%) \downarrow
Average	94.92% (14.72%)\uparrow	94.92% (14.92%)\uparrow	19.96% (60.24%)\downarrow	19.89% (60.11%)\downarrow	86.77% (6.57%)\uparrow	86.77% (6.77%)\uparrow	92.79% (12.59%)\uparrow	92.8% (12.81%)\uparrow	89.05% (8.85%)\uparrow	89.07% (9.07%)\uparrow
Model	Packet Loss 20%									
	ZeroPad		Markov		BERT		Roberta		Deberta	
Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	
CNN	91.02% (13.69%) \uparrow	90.94% (13.40%) \uparrow	20.00% (57.33%) \downarrow	19.76% (57.78%) \downarrow	83.00% (5.67%) \uparrow	83.10% (5.56%) \uparrow	91.13% (13.8%) \uparrow	91.05% (13.51%) \uparrow	85.20% (7.87%) \uparrow	85.03% (7.49%) \uparrow
LSTM	85.7% (30.10%) \uparrow	85.61% (30.82%) \uparrow	20.05% (35.55%) \downarrow	19.77% (35.02%) \downarrow	75.32% (19.72%) \uparrow	75.18% (20.39%) \uparrow	78.52% (22.92%) \uparrow	78.03% (23.24%) \uparrow	77.72% (22.12%) \uparrow	77.63% (22.84%) \uparrow
GRU	87.51% (31.40%) \uparrow	87.38% (32.14%) \uparrow	20.16% (35.95%) \downarrow	19.86% (35.38%) \downarrow	74.09% (17.98%) \uparrow	74.00% (18.76%) \uparrow	80.49% (24.38%) \uparrow	80.2% (24.96%) \uparrow	76.89% (20.78%) \uparrow	76.74% (21.5%) \uparrow
TST	92.99% (10.18%) \uparrow	92.86% (9.87%) \uparrow	19.98% (62.83%) \downarrow	19.72% (63.27%) \downarrow	82.20% (0.61%) \downarrow	82.16% (0.83%) \downarrow	92.39% (9.58%) \uparrow	92.29% (9.30%) \uparrow	85.00% (2.19%) \uparrow	84.96% (1.97%) \uparrow
SDAE	82.47% (35.22%) \uparrow	82.62% (35.92%) \uparrow	19.95% (27.30%) \downarrow	19.58% (27.12%) \downarrow	72.84% (25.59%) \uparrow	72.74% (26.04%) \uparrow	77.27% (30.02%) \uparrow	77.4% (30.70%) \uparrow	74.94% (27.69%) \uparrow	75.04% (28.34%) \uparrow
FS-Net	95.14% (4.73%) \uparrow	95.16% (4.64%) \uparrow	19.75% (70.77%) \downarrow	18.56% (3.85%) \downarrow	86.56% (3.56%) \downarrow	86.96% (3.56%) \downarrow	79.96% (10.45%) \downarrow	80.41% (10.11%) \downarrow	88.86% (1.55%) \downarrow	89.18% (1.34%) \downarrow
Average	89.14% (20.89%)\uparrow	89.21% (21.13%)\uparrow	20.02% (48.24%)\downarrow	19.74% (48.22%)\downarrow	79.00% (10.75%)\uparrow	79.02% (11.06%)\uparrow	83.29% (5.85%)\uparrow	83.23% (5.87%)\uparrow	81.44% (13.18%)\uparrow	81.43% (13.47%)\uparrow
Model	Packet Loss 30%									
	ZeroPad		Markov		BERT		Roberta		Deberta	
Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	
CNN	84.19% (19.93%) \uparrow	84.03% (19.41%) \uparrow	20.07% (44.19%) \downarrow	19.46% (45.16%) \uparrow	76.56% (12.3%) \downarrow	77.76% (13.14%) \downarrow	84.40% (20.14%) \uparrow	84.22% (19.6%) \uparrow	80.06% (15.80%) \uparrow	79.71% (15.09%) \uparrow
LSTM	76.47% (31.01%) \uparrow	76.38% (31.90%) \uparrow	20.29% (25.17%) \uparrow	19.66% (24.82%) \downarrow	66.67% (21.21%) \downarrow	65.72% (21.24%) \downarrow	65.61% (20.15%) \uparrow	64.55% (20.07%) \uparrow	69.08% (23.62%) \uparrow	68.79% (24.31%) \uparrow
GRU	78.80% (32.66%) \uparrow	78.61% (33.94%) \uparrow	20.42% (25.72%) \uparrow	19.82% (24.85%) \downarrow	65.22% (19.08%) \uparrow	64.38% (19.71%) \uparrow	67.42% (21.28%) \uparrow	66.66% (21.99%) \uparrow	68.72% (22.58%) \uparrow	68.39% (23.72%) \uparrow
TST	86.49% (14.48%) \uparrow	86.32% (13.89%) \uparrow	19.85% (52.16%) \downarrow	19.12% (53.31%) \downarrow	75.43% (3.42%) \uparrow	74.72% (2.29%) \uparrow	85.48% (13.47%) \uparrow	85.33% (12.9%) \uparrow	78.23% (6.22%) \uparrow	78.26% (5.83%) \uparrow
SDAE	74.72% (35.94%) \uparrow	74.99% (36.77%) \uparrow	19.90% (18.88%) \uparrow	19.16% (19.06%) \uparrow	62.61% (23.83%) \uparrow	61.97% (23.75%) \uparrow	64.41% (25.63%) \uparrow	64.43% (26.21%) \uparrow	66.41% (27.63%) \uparrow	66.47% (28.25%) \uparrow
FS-Net	91.06% (7.40%) \uparrow	91.01% (7.14%) \uparrow	19.96% (63.70%) \uparrow	19.49% (64.38%) \uparrow	76.29% (7.37%) \uparrow	76.72% (7.15%) \uparrow	64.91% (18.75%) \uparrow	64.41% (19.46%) \downarrow	80.09% (3.57%) \downarrow	80.71% (3.16%) \downarrow
Average	81.96% (23.57%)\uparrow	81.89% (23.84%)\uparrow	20.08% (38.30%)\downarrow	19.45% (38.60%)\downarrow	70.46% (12.08%)\uparrow	70.21% (12.16%)\uparrow	72.04% (13.65%)\uparrow	71.6% (13.55%)\uparrow	73.77% (15.38%)\uparrow	73.72% (15.67%)\uparrow

TABLE XXXIII
CLASSIFICATION ACCURACY WITH DIFFERENT FEATURE IMPUTATION METHODS IN d_3 .

Model	Packet Loss 10%									
	ZeroPad		Markov		BERT		Roberta		Deberta	
Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	
CNN	74.78% (6.79%) \uparrow	74.97% (7.10%) \uparrow	20.33% (47.66%) \downarrow	20.16% (47.71%) \downarrow	71.06% (3.07%) \uparrow	78.55% (10.68%) \uparrow	74.06% (6.07%) \uparrow	74.05% (6.18%) \uparrow	81.19% (13.2%) \uparrow	81.2% (13.33%) \uparrow
LSTM	81.32% (17.53%) \uparrow	81.31% (17.94%) \uparrow	20.34% (43.45%) \downarrow	19.99% (43.38%) \downarrow	75.84% (12.05%) \uparrow	86.8% (23.43%) \uparrow	79.64% (15.85%) \uparrow	79.55% (16.18%) \uparrow	88.60% (24.81%) \uparrow	88.62% (25.25%) \uparrow
GRU	75.73% (13.43%) \uparrow	75.67% (13.63%) \uparrow	20.45% (41.85%) \downarrow	20.08% (41.96%) \downarrow	70.59% (8.29%) \uparrow	78.69% (16.65%) \uparrow	74.59% (12.29%) \uparrow	74.42% (12.38%) \uparrow	81.29% (18.99%) \uparrow	81.24% (19.20%) \uparrow
TST	86.49% (14.48%) \uparrow	86.32% (13.89%) \uparrow	19.85% (52.16%) \downarrow	19.12% (53.31%) \downarrow	75.43% (3.42%) \uparrow	74.72% (2.29%) \uparrow	85.48% (13.47%) \uparrow	85.33% (12.9%) \uparrow	78.23% (6.22%) \uparrow	78.26% (5.83%) \uparrow
SDAE	74.72% (35.94%) \uparrow	74.99% (36.77%) \uparrow	19.90% (18.88%) \uparrow	19.16% (19.06%) \uparrow	62.61% (23.83%) \uparrow	61.97% (23.75%) \uparrow	64.41% (25.63%) \uparrow	64.43% (26.21%) \uparrow	66.41% (27.63%) \uparrow	66.47% (28.25%) \uparrow
FS-Net	91.06% (7.40%) \uparrow	91.01% (7.14%) \uparrow	19.96% (63.70%) \uparrow	19.49% (64.38%) \uparrow	76.29% (7.37%) \uparrow	76.72% (7.15%) \uparrow	64.91% (18.75%) \uparrow	64.41% (19.46%) \downarrow	80.09% (3.57%) \downarrow	80.71% (3.16%) \downarrow
Average	77.49% (9.42%)\uparrow	76.87% (9.66%)\uparrow	20.35% (47.72%)\downarrow	19.52% (47.69%)\downarrow	72.95% (4.49%)\uparrow	80.26% (13.05%)\uparrow	76.54% (8.47%)\uparrow	82.94% (14.88%)\uparrow	82.36% (15.15%)\uparrow	
Model	Packet Loss 20%									
	ZeroPad		Markov		BERT		Roberta		Deberta	
Acc	F1	Acc	F1	Acc	F1	Acc	F1	Acc	F1	
CNN	66.39% (5.24%) \uparrow	66.32% (5.72%) \uparrow	20.48% (40.67%) \downarrow	20.05% (40.55%) \downarrow	63.09% (1.94%) \uparrow	63.16% (2.56%) \uparrow	65.60% (3.90%) \uparrow	65.05% (17.82%) \uparrow	78.42% (17.27%) \uparrow	78.46% (17.86%) \uparrow
LSTM	70.99% (16.12%) \uparrow	70.69% (16.71%) \uparrow	20.71% (34.16%) \downarrow	19.91% (34.07%) \downarrow	66.25% (11.38%) \uparrow	66.47% (13.41%) \uparrow	68.38% (30.34%) \uparrow	84.32% (29.45%) \uparrow	84.34% (30.36%) \uparrow	
GRU	67.69% (13.47%) \uparrow	67.46% (13.49%) \uparrow	20.96% (33.26%) \downarrow	20.19% (33.78%) \downarrow	62.99% (8.77%) \uparrow	63.1% (9.13%) \uparrow	66.29% (11.51%) \uparrow	65.73% (24.43%) \uparrow	78.40% (24.18%) \uparrow	78.33% (24.36%) \uparrow
TST	70.24% (7.64%) \uparrow	69.32% (7.77%) \uparrow	21.38% (41.22%) \downarrow	20.22% (41.33%) \downarrow	67.36% (4.76%) \uparrow	66.89% (5.34%) \uparrow	69.86% (6.44%) \uparrow	69.04% (25.22%) \uparrow	86.77% (24.17%) \uparrow	86.75% (25.20%) \uparrow
SDAE	66.03% (9.11%) \uparrow	65.84% (9.91%) \uparrow	20.41% (36.51%) \downarrow	19.96% (35.97%) \downarrow	61.28% (4.36%) \uparrow	61.52% (5.59%) \uparrow	64.99% (7.55%) \uparrow	64.47% (16.67%) \uparrow	72.60% (16.58%) \uparrow	72.35% (16.42%) \uparrow
FS-Net	69.07% (3.04%) \uparrow	64.33% (3.38%) \uparrow	19.49% (46.57%) \uparrow	16.50% (44.29%) \uparrow	57.21% (8.85%) \uparrow	57.57% (3.22%) \uparrow	59.61% (1.18%) \uparrow	58.00% (11.07%) \uparrow	78.44% (12.38%) \uparrow	74.77% (13.98%) \uparrow
Average	62.13% (7.									

TABLE XXXV
CLASSIFICATION ACCURACY WITH TFM SUB-STRATEGIES IN d_1 , d_2 , d_3 AND d_4 .

Scenario d1		Imputed Loss 10%				Imputed Loss 20%				Imputed Loss 30%			
Model		TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS
CNN	86.91%	86.42%	83.19%	82.25%	82.56%	82.48%	77.75%	76.06%	78.91%	78.92%	72.80%	71.29%	
LSTM	88.04%	87.93%	85.06%	83.78%	84.28%	84.05%	78.92%	77.23%	81.34%	80.85%	73.62%	72.88%	
GRU	86.54%	86.57%	83.60%	82.31%	83.13%	82.72%	77.57%	75.86%	79.35%	79.41%	72.94%	71.35%	
TST	91.03%	90.88%	86.23%	84.21%	86.11%	86.05%	78.69%	76.45%	71.08%	70.97%	68.41%	68.06%	
SDAE	72.29%	72.27%	71.16%	70.97%	71.69%	71.71%	70.32%	69.77%	81.65%	81.74%	72.47%	71.24%	
FS-Net	90.23%	90.29%	89.56%	89.27%	88.89%	88.60%	86.70%	86.44%	86.13%	86.48%	82.73%	82.26%	
Average	85.84%	85.73%	83.13%	82.13%	82.78%	82.60%	78.33%	76.97%	79.74%	79.73%	73.83%	72.85%	
Scenario d2	Imputed Loss 10%				Imputed Loss 10%				Imputed Loss 10%				
Model		TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS
CNN	99.29%	99.36%	98.6%	96.26%	97.95%	98.33%	96.77%	96.26%	95.45%	96.35%	93.69%	96.26%	
LSTM	97.68%	98.08%	97.19%	93.35%	94.75%	95.89%	93.31%	93.35%	90.82%	92.13%	87.34%	93.35%	
GRU	97.89%	98.24%	97.27%	93.59%	94.83%	95.65%	93.49%	93.59%	91%	91.99%	89.11%	93.59%	
TST	99.24%	99.2%	98.71%	98.05%	98.18%	98.33%	97.08%	98.05%	96.32%	96.7%	94.16%	98.05%	
SDAE	95.6%	95.65%	94.84%	91.32%	93.59%	94.03%	92.09%	91.32%	90.81%	91.5%	87.66%	91.32%	
FS-Net	99.85%	99.84%	99.69%	98.05%	99.63%	99.64%	99.38%	96.31%	99.39%	99.36%	98.59%	94.87%	
Average	98.26%	98.4%	97.72%	95.1%	96.49%	96.98%	95.35%	94.81%	93.97%	94.67%	91.76%	94.57%	
Scenario d3	Imputed Loss 10%				Imputed Loss 20%				Imputed Loss 30%				
Model		TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS
CNN	82.40%	82.45%	80.24%	78.5%	79.93%	80.22%	76.25%	73.99%	77.48%	77.91%	72.64%	69.88%	
LSTM	89.51%	89.61%	87.24%	85.08%	85.85%	86.09%	81.39%	78.57%	82.11%	82.46%	75.76%	72.69%	
GRU	82.15%	82.23%	80.53%	78.93%	79.70%	79.93%	76.22%	74.30%	77.18%	77.59%	72.81%	70.07%	
TST	93.05%	93.06%	90.36%	87.39%	88.87%	89.14%	83.49%	79.22%	84.09%	84.66%	76.94%	72.23%	
SDAE	73.96%	74.05%	73.22%	72.54%	73.11%	73.27%	71.23%	70.64%	71.98%	72.18%	69.26%	68.05%	
FS-Net	81.61%	81.43%	80.90%	80.10%	80.75%	80.69%	79.44%	77.99%	79.59%	79.40%	76.93%	75.11%	
Average	83.78%	83.81%	82.08%	80.42%	81.37%	81.56%	78.00%	75.79%	78.74%	79.03%	74.06%	71.34%	
Scenario d4	Imputed Loss 10%				Imputed Loss 20%				Imputed Loss 30%				
Model		TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS	TFM-Mask	TFM-Del	TFM-Span	TFM-PS
CNN	82.51%	82.57%	81.65%	81.22%	81.31%	81.30%	79.50%	78.83%	79.97%	80.07%	77.19%	76.66%	
LSTM	82.50%	82.50%	81.69%	81.27%	81.35%	81.29%	79.58%	79.23%	79.99%	80.08%	77.84%	77.36%	
GRU	82.18%	82.10%	81.19%	80.93%	80.42%	80.38%	78.78%	78.34%	78.90%	79.04%	76.60%	76.09%	
TST	83.17%	83.18%	82.43%	82.03%	82.12%	82.20%	80.55%	79.66%	80.90%	80.90%	78.07%	77.38%	
SDAE	65.74%	65.72%	65.47%	65.28%	65.51%	65.49%	64.65%	64.61%	64.84%	64.83%	63.68%	63.52%	
FS-Net	81.60%	81.61%	81.29%	81.34%	81.02%	81.07%	80.50%	80.34%	80.41%	80.44%	79.29%	79.19%	
Average	79.62%	79.61%	78.95%	78.68%	78.62%	78.62%	77.26%	76.84%	77.5%	77.56%	75.45%	75.03%	

TABLE XXXVI
CLASSIFICATION ACCURACY OF DIFFERENT SEQUENCE LENGTH IN SCENARIO d_1 .

Model	Sequence length: 256						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	90.67%	62.89%	85.13%(22.24%↑)	54.27%	85.40%(20.81%↑)	52.03%	76.01%(23.98%↑)
LSTM	89.88%	60.61%	86.43%(25.82%↑)	51.16%	82.47%(31.31%↑)	50.67%	77.78%(27.11%↑)
GRU	87.61%	58.14%	84.76%(26.62%↑)	44.79%	80.46%(35.67%↑)	40.26%	76.60%(36.34%↑)
TST	94.50%	69.95%	88.2%(18.25%↑)	61.29%	81.84%(20.55%↑)	57.01%	77.64%(20.63%↑)
SDAE	70.86%	61.34%	70.17%(8.83%↑)	55.67%	69.5%(13.83%↑)	56.35%	68.53%(12.18%↑)
FS-Net	82.16%	79.75%	80.89%(1.14%↑)	76.27%	79.35%(3.08%↑)	71.12%	77.53%(6.41%↑)
Average	85.95%	65.45%	82.60%(17.15%↑)	57.24%	78.98%(21.74%↑)	54.57%	75.68%(21.11%↑)
Model	Sequence length: 1024						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	90.31%	64.59%	85.40%(20.81%↑)	56.76%	80.72%(23.96%↑)	54.26%	76.58%(22.32%↑)
LSTM	89.26%	61.03%	85.8%(24.77%↑)	51.80%	81.76%(29.96%↑)	51.07%	78.16%(27.09%↑)
GRU	87.21%	59.63%	84.16%(24.53%↑)	45.67%	80.28%(34.61%↑)	40.84%	76.44%(35.60%↑)
TST	94.46%	70.08%	87.88%(17.8%↑)	61.53%	81.54%(20.01%↑)	57.50%	77.23%(19.73%↑)
SDAE	74.61%	62.07%	73.89%(11.82%↑)	55.78%	73.20%(17.42%↑)	56.39%	72.13%(15.74%↑)
FS-Net	94.49%	91.59%	92.77%(1.18%↑)	87.12%	90.35%(3.23%↑)	81.33%	87.64%(6.31%↑)
Average	88.39%	68.17%	84.98%(16.81%↑)	59.78%	81.31%(21.53%↑)	56.90%	78.03%(21.13%↑)

TABLE XXXVII
CLASSIFICATION ACCURACY OF DIFFERENT SEQUENCE LENGTH IN SCENARIO d_2 .

Model	Sequence length: 256						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	99.73%	86.35%	97.85%(11.50%↑)	71.17%	99.14%(9.93%↑)	56.42%	91.89%(35.47%↑)
LSTM	99.07%	69.69%	96.90%(27.21%↑)	55.13%	94.59%(39.46%↑)	45.94%	91.21%(45.27%↑)
GRU	99.05%	72.21%	97.74%(25.53%↑)	56.85%	95.52%(38.67%↑)	46.79%	92.85%(46.06%↑)
TST	99.93%	93.07%	99.87%(6.80%↑)	82.80%	99.76%(16.96%↑)	70.72%	99.42%(28.70%↑)
SDAE	94.71%	56.32%	93.58%(37.26%↑)	41.82%	91.39%(49.57%↑)	35.06%	88.32%(53.26%↑)
FS-Net	99.95%	99.11%	99.93%(0.82%↑)	97.27%	99.86%(2.59%↑)	93.72%	99.73%(6.01%↑)
Average	98.74%	79.46%	97.65%(18.19%↑)	67.51%	95.98%(28.47%↑)	58.11%	93.9%(35.79%↑)
Model	Sequence length: 1024						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	99.75%	89.21%	99.14%(9.93%↑)	78.58%	97.38%(18.8%↑)	67.72%	94.35%(26.63%↑)
LSTM	99.06%	69.94%	98.11%(28.17%↑)	56.47%	95.48%(39.01%↑)	47.97%	91.54%(43.57%↑)
GRU	99.00%	70.61%	98.22%(27.61%↑)	56.00%	95.95%(39.95%↑)	46.17%	92.47%(46.30%↑)
TST	99.84%	93.20%	99.40%(6.20%↑)	99.4%	99.4%(17.35%↑)	68.74%	96.27%(27.53%↑)
SDAE	94.41%	57.12%	93.73%(36.61%↑)	42.24%	92.12%(49.88%↑)	34.83%	89.66%(54.83%↑)
FS-Net	99.92%	98.64%	99.89%(1.25%↑)	95.79%	99.77%(3.98%↑)	90.70%	99.57%(8.87%↑)
Average	98.66%	79.79%	98.08%(18.29%↑)	68.52%	96.68%(28.16%↑)	59.36%	93.98%(34.62%↑)

TABLE XXXVIII
CLASSIFICATION ACCURACY OF DIFFERENT SEQUENCE LENGTH IN SCENARIO d_3 .

Model	Sequence length: 256						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	83.91%	67.76%	80.3%(12.54%↑)	60.35%	81.1%(13.93%↑)	55.42%	74.94%(19.52%↑)
LSTM	93.22%	63.75%	89.23%(25.48%↑)	54.91%	84.41%(29.5%↑)	47.4%	80.11%(32.71%↑)
GRU	85.6%	61.2%	81.88%(20.68%↑)	53.55%	78.25%(24.7%↑)	46.86%	75.55%(28.69%↑)
TST	95.47%	73.36%	91.62%(18.26%↑)	63.41%	86.51%(23.1%↑)	57.22%	81.33%(24.11%↑)
SDAE	77.39%	64.42%	76.23%(11.81%↑)	57.1%	74.6%(17.5%↑)	50.72%	73.05%(22.33%↑)
FS-Net	84.08%	80.55%	83.16%(2.61%↑)	75.2%	81.77%(6.57%↑)	69.04%	80.08%(11.04%↑)
Average	86.61%	68.51%	83.74%(15.23%↑)	60.75%	80.49%(19.74%↑)	54.44%	77.51%(23.07%↑)
Model	Sequence length: 1024						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	84.3%	67.17%	81.1%(13.93%↑)	60.2%	78.06%(17.86%↑)	55.13%	75.24%(20.11%↑)
LSTM	93.52%	63.33%	89.77%(26.44%↑)	54.5%	84.85%(30.35%↑)	47.29%	80.47%(33.18%↑)
GRU	85.68%	62.19%	82.29%(20.1%↑)	54.22%	78.73%(24.51%↑)	48.38%	75.86%(27.48%↑)
TST	95.95%	70.14%	91.99%(21.85%↑)	60.69%	86.44%(25.75%↑)	55.32%	81%(25.68%↑)
SDAE	72.01%	59.78%	70.96%(11.18%↑)	53.22%	69.51%(16.29%↑)	48.58%	68.31%(19.73%↑)
FS-Net	83.77%	80.3%	82.82%(2.52%↑)	74.89%	81.52%(6.63%↑)	69.63%	80.02%(10.39%↑)
Average	85.87%	67.15%	83.16%(16.01%↑)	59.62%	79.85%(20.23%↑)	54.06%	76.82%(22.76%↑)

TABLE XXXIX
CLASSIFICATION ACCURACY OF DIFFERENT SEQUENCE LENGTH IN SCENARIO d_4 .

Model	Sequence length: 256						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	83.46%	59.70%	82.01%(22.31%↑)	50.74%	82.22%(22.13%↑)	41.01%	78.70%(37.69%↑)
LSTM	83.46%	51.32%	82.21%(30.89%↑)	48.63%	80.86%(32.23%↑)	39.28%	79.19%(39.91%↑)
GRU	83.35%	48.93%	81.73%(32.80%↑)	43.48%	79.71%(36.23%↑)	37.97%	77.93%(39.96%↑)
TST	83.66%	65.72%	82.76%(17.04%↑)	55.41%	81.48%(26.07%↑)	43.00%	79.91%(36.91%↑)
SDAE	69.69%	54.54%	69.21%(14.67%↑)	46.87%	68.53%(21.66%↑)	36.69%	67.50%(30.81%↑)
FS-Net	82.22%	79.70%	81.76%(2.06%↑)	71.6%	81.09%(9.49%↑)	65.49%	80.45%(14.96%↑)
Average	80.97%	59.99%	79.95%(19.96%↑)	52.79%	78.72%(25.93%↑)	43.91%	77.28%(33.37%↑)
Model	Sequence length: 1024						
	Normal	Loss 10%	Imputed Loss 10%	Loss 20%	Imputed Loss 20%	Loss 30%	Imputed Loss 30%
CNN	83.61%	60.09%	82.22%(22.13%↑)	51.68%	80.68%(29.00%↑)	41.67%	78.83%(37.16%↑)
LSTM	83.45%	50.64%	82.26%(31.62%↑)	48.05%	80.88%(32.83%↑)	38.67%	79.44%(40.77%↑)
GRU	83.23%	49.40%	81.62%(32.22%↑)	44.58%	79.92%(35.34%↑)	38.15%	78.28%(40.13%↑)
TST	83.61%	65.22%	91.99%(26.77%↑)	60.69%	86.44%(25.75%↑)	55.32%	81.00%(25.68%↑)
SDAE	67.91%	55.09%	67.54%(12.45%↑)	47.94%	67.09%(19.15%↑)	37.00%	66.32%(29.32%↑)
FS-Net	83.77%	80.30%	82.82%(2.52%↑)	74.89%	81.52%(6.63%↑)	69.63%	80.02%(10.39%↑)
Average	80.93%	60.12%	81.41%(21.29%↑)	54.64%	79.42%(24.78%↑)	46.74%	77.32%(30.58%↑)

TABLE XL
AVERAGE PERFORMANCE VARIATION WITH DIFFERENT MAIN STRUCTURE.

Structure	Imputed Loss 10%		Imputed Loss 10%		Imputed Loss 10%	
	Acc	F1	Acc	F1	Acc	F1
RepFNN	90.63%(5.69%↓)	90.55%(5.75%↓)	79.16%(12.20%↓)	78.6%(12.60%↓)	64.07%(19.81%↓)	64.83%(19.10%↓)
RepCNN	94.77%(1.55%↓)	94.74%(1.56%↓)	88.16%(3.20%↓)	88.19%(3.01%↓)	74.05%(9.83%↓)	74.53%(9.40%↓)
RepLSTM	94.41%(1.91%↓)	94.37%(1.93%↓)	88.54%(2.82%↓)	88.36%(2.84%↓)	78.19%(5.69%↓)	78.21%(5.720%↓)