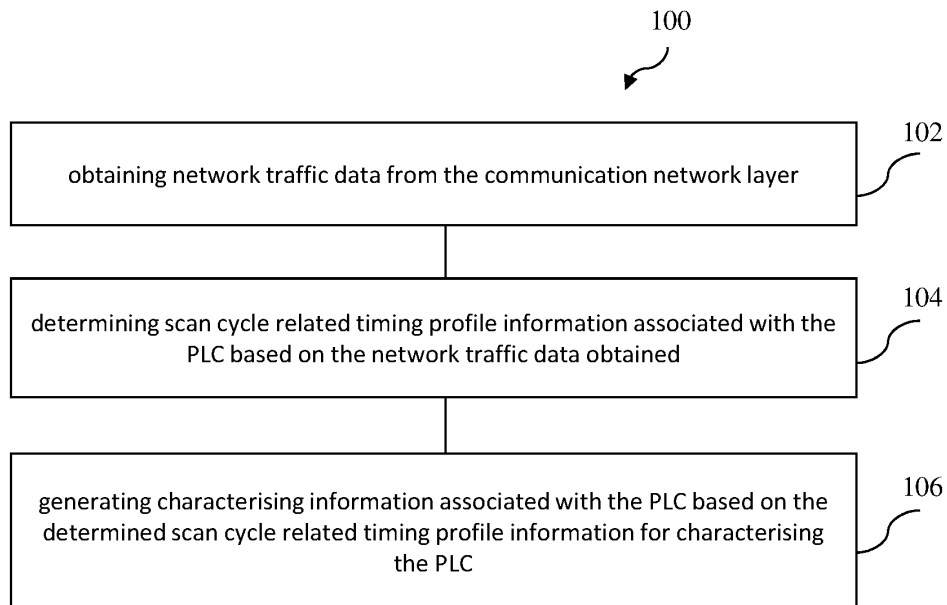
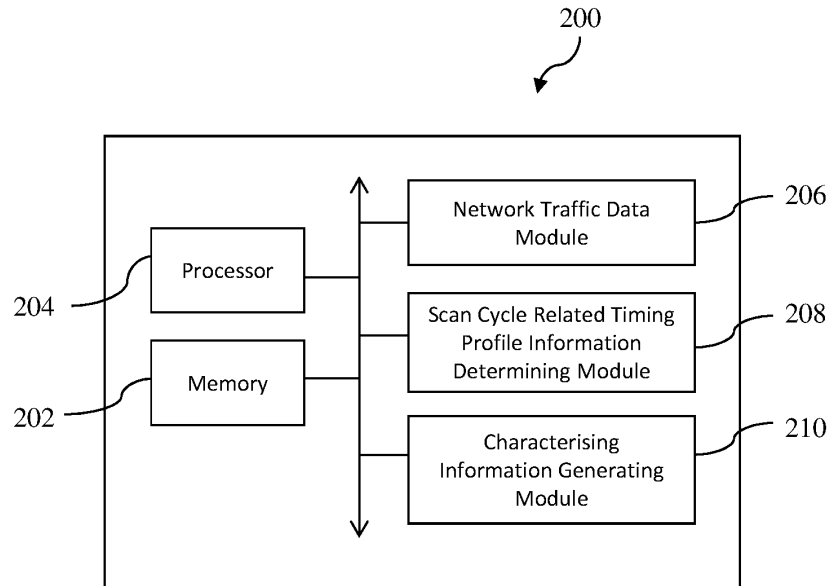


**FIG. 1****FIG. 2**

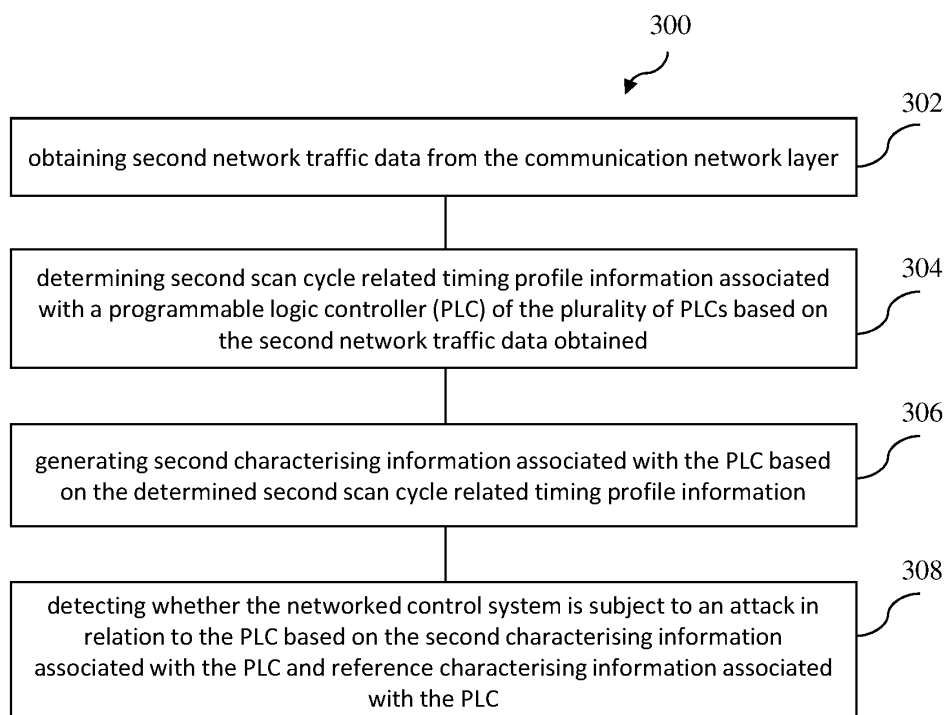


FIG. 3

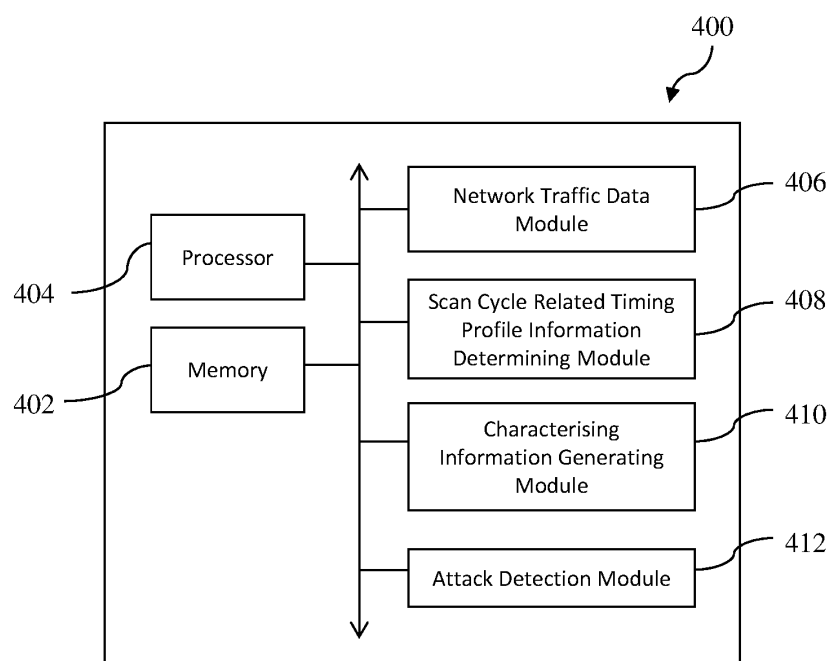


FIG. 4

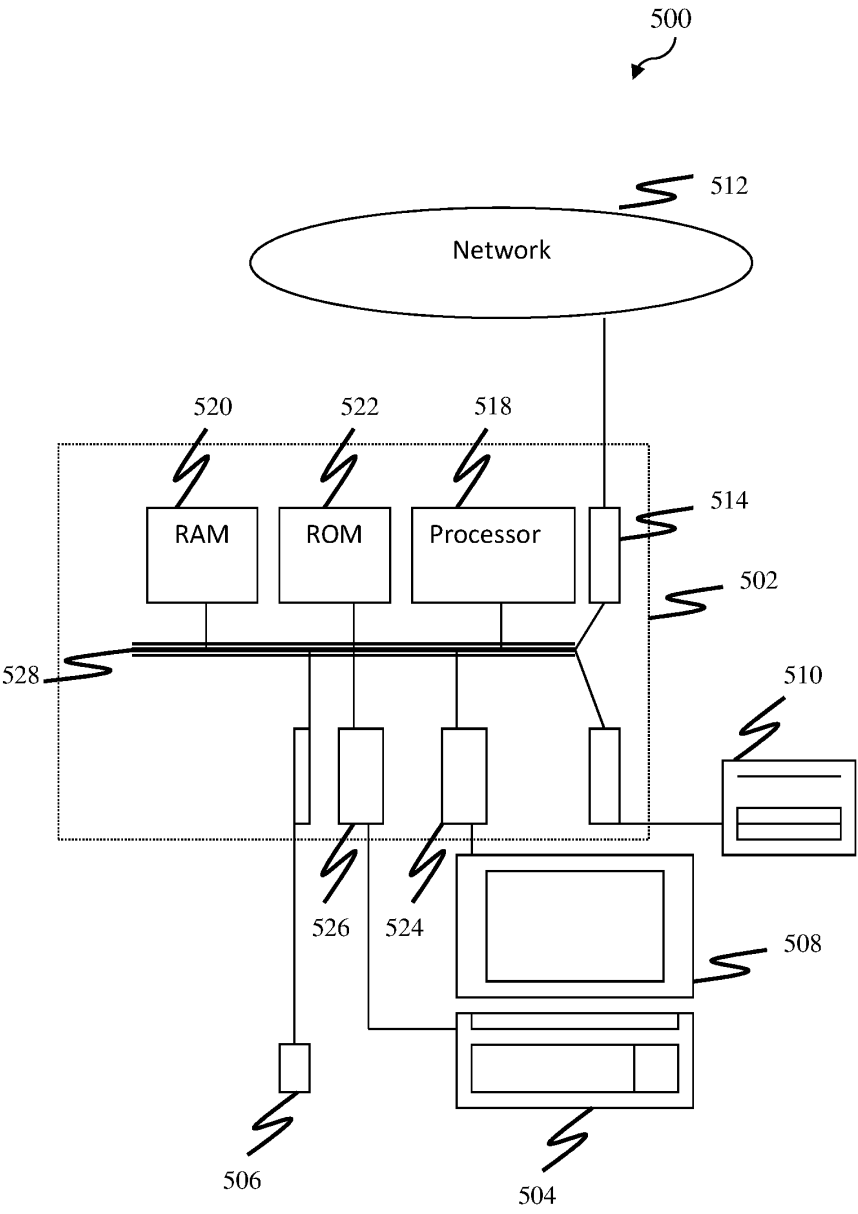


FIG. 5

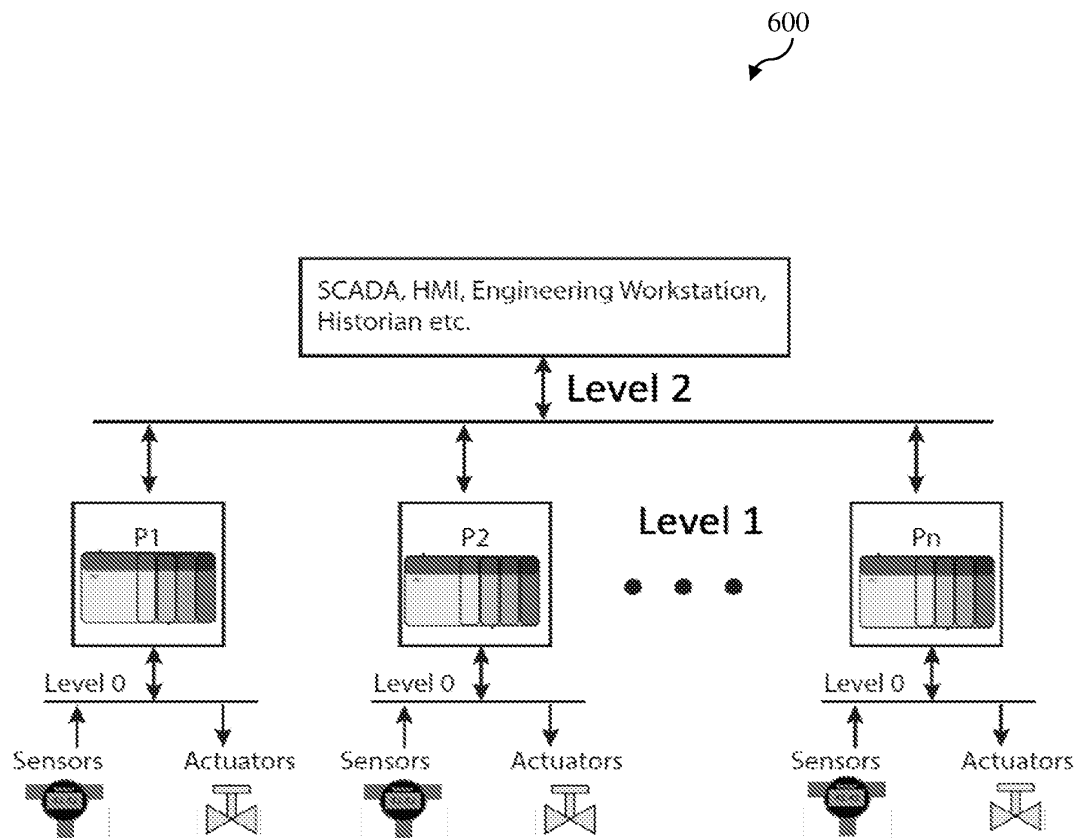


FIG. 6

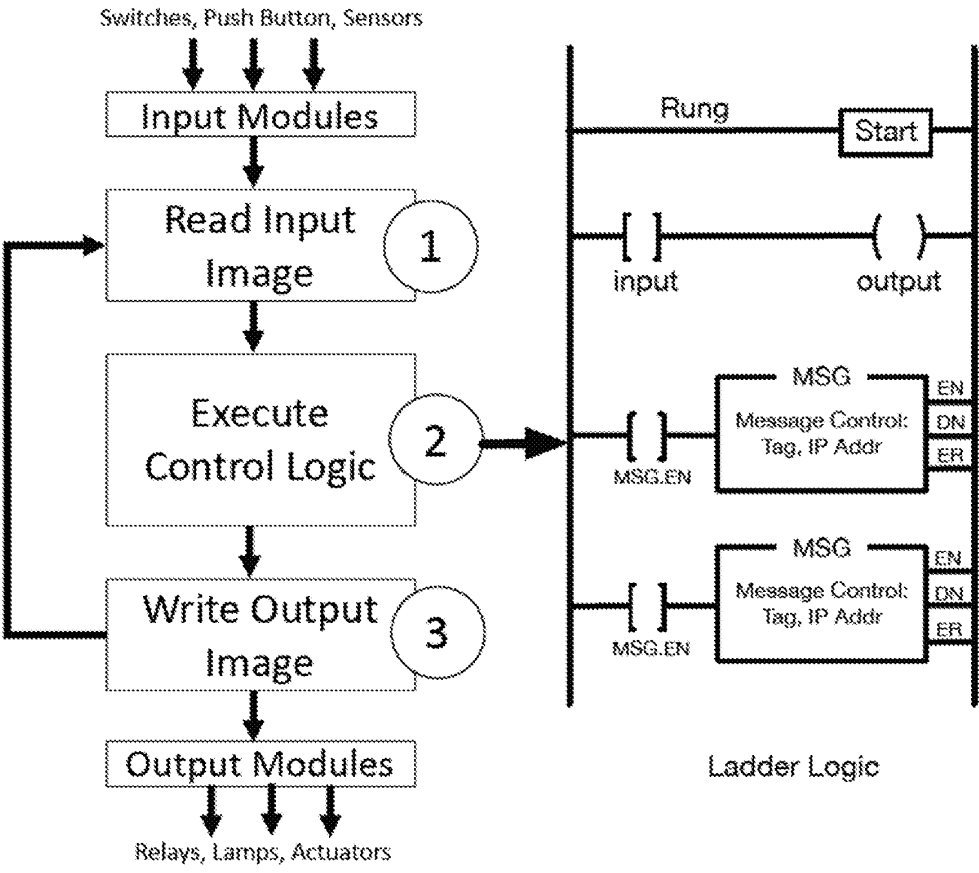
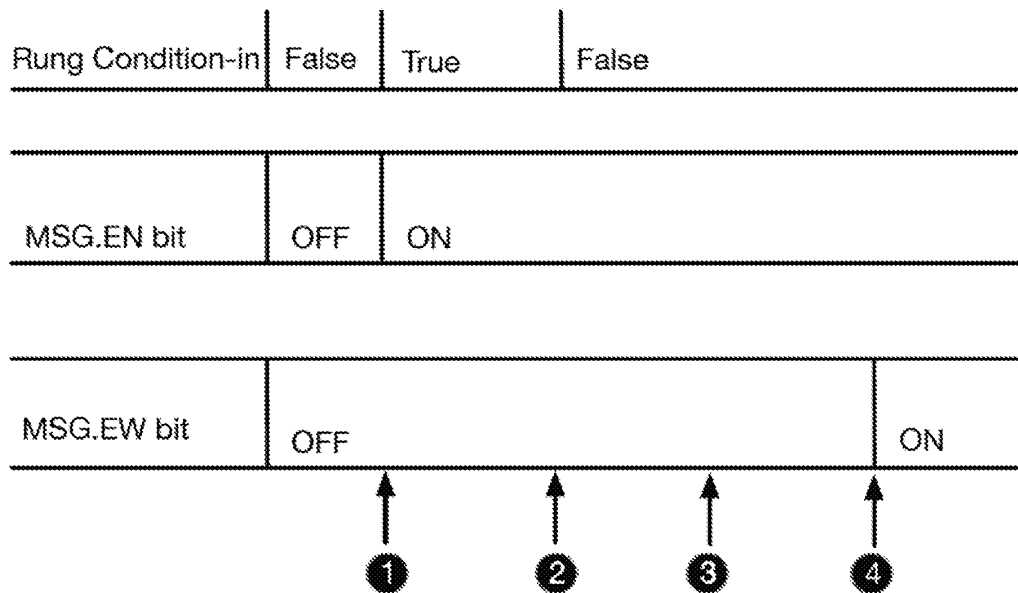


FIG. 7

Table 1

PLC X To PLC Y	MSG Instruction	$E[T_{SC}]$ (ms)	$E[T_{Resp}]$ (ms)	$E[T_{ESC}]$ (ms)	$E[\eta] = \frac{E[T_{ESC}]}{E[T_{SC}]}$ if $T_{SC} << T_{OH}$	$E[\eta] = \frac{E[T_{ESC}]}{E[T_{SC}]}$ if $T_{SC} >> T_{OH}$
PLC 1: PLC 2	FIT-201 IP: x.x.1.20	4.387	8.597	22.153	5.34	1.96
PLC 2: PLC 3	LIT-301 IP: x.x.1.30	4.708	8.273	34.327	7.04	1.98
PLC 3: PLC 2	MV-201 IP: x.x.1.20	4.117	11.062	39.814	9.75	1.97
PLC 4: PLC 5	MV-501 IP: x.x.1.50	4.045	18.905	44.529	10.04	1.96
PLC 5: PLC 4	FIT-401 IP: x.x.1.40	5.078	12.804	57.126	11.08	1.97
PLC 6: PLC 1	LIT-101 IP: x.x.1.10	2.721	3.13	25.364	9.32	1.97

FIG. 8**FIG. 9**

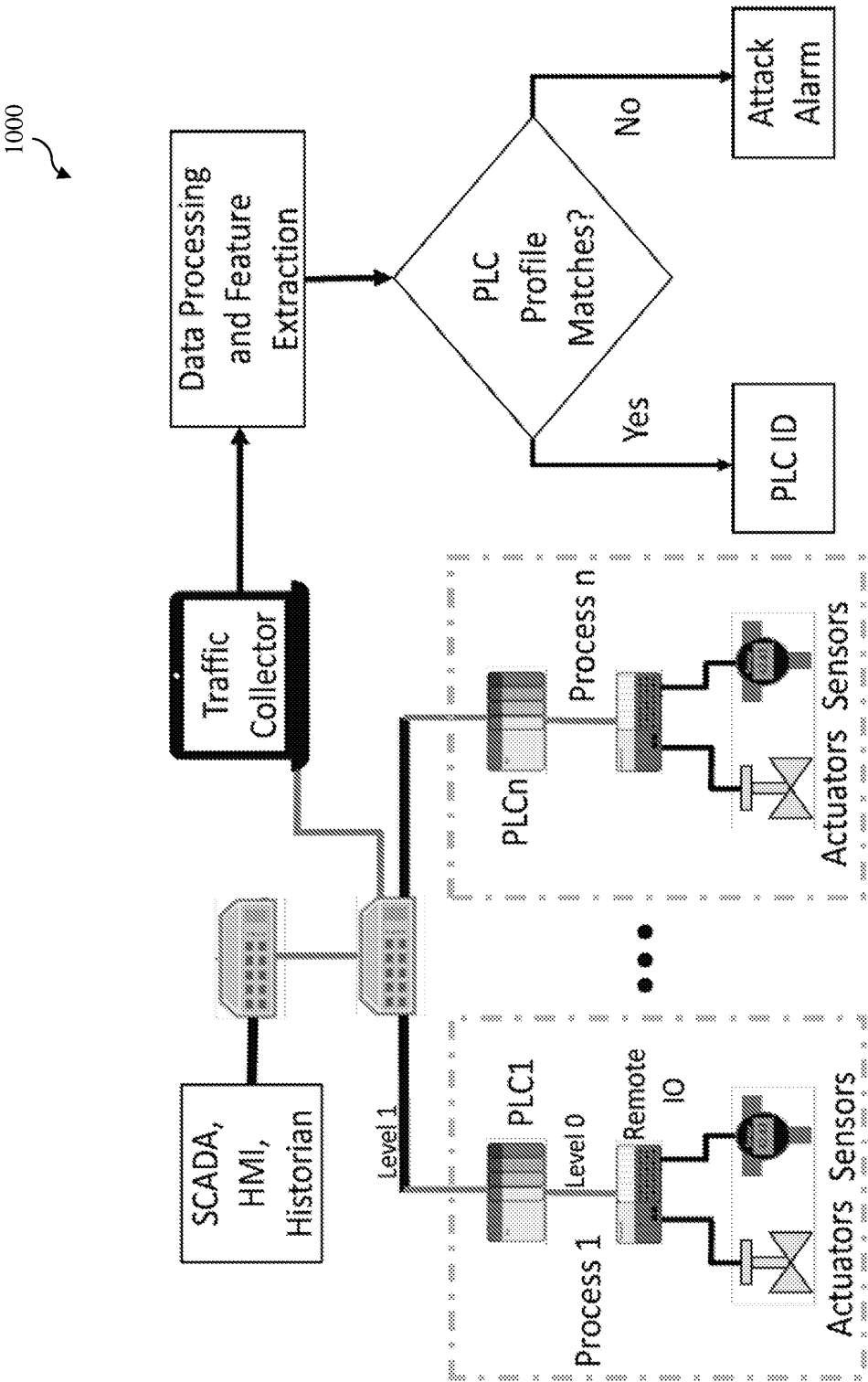


FIG. 10

Table 2

Feature	Description	IV
Mean	$\bar{x} = \frac{1}{N} \sum_{l=1}^N x_l$	0.5
Std-Dev	$\sigma = \sqrt{\frac{1}{N-1} \sum_{l=1}^N (x_l - \bar{x})^2}$	0.5
Mean Avg. Dev	$D_{\bar{x}} = \frac{1}{N} \sum_{l=1}^N x_l - \bar{x} $	0.5
Skewness	$\gamma = \frac{1}{N} \sum_{l=1}^N \left(\frac{x_l - \bar{x}}{\sigma} \right)^3$	0.041
Kurtosis	$\beta = \frac{1}{N} \sum_{l=1}^N \left(\frac{x_l - \bar{x}}{\sigma} \right)^4 - 3$	0.063
Spec. Std-Dev	$\sigma_s = \sqrt{\frac{\sum_{i=1}^N (y_f(i)^2) * y_m(i)}{\sum_{i=1}^N y_m(i)}}$	0.5
Spec. Centroid	$C_s = \frac{\sum_{i=1}^N (y_f(i)) * y_m(i)}{\sum_{i=1}^N y_m(i)}$	0.5
DC Component	$y_m(0)$	0.6
Spectral Crest	$SC_s = \frac{(Max_{i=1 to N}(y_m(i)))}{C_s}$	0.42
Smoothness	$S_s = \frac{\sum_{i=2}^{N-1} 20 \cdot \log(y_m(i)) - 20(\log(y_m(i-1)) + \log(y_m(i)) + \log(y_m(i+1))) }{3}$	0.5
Spectral Flatness	$F_s = \frac{(\prod_{i=1}^N y_m(i))^{1/N}}{\frac{\sum_{i=1}^N y_m(i)}{N}}$	0.5
Spectral Skewness	$\gamma_s = \frac{\sum_{i=1}^N (y_m(i) - C_s)^3 * y_m(i)}{\sigma_s^3}$	0.5
Spectral Kurtosis	$\beta_s = \frac{\sum_{i=1}^N (y_m(i) - C_s)^4 * y_m(i)}{\sigma_s^4 - 3}$	0.5

x : time domain data from a sensor for N elements in the data chunk; y_f : bin frequencies; y_m : magnitude of the frequency coefficients.

FIG. 11

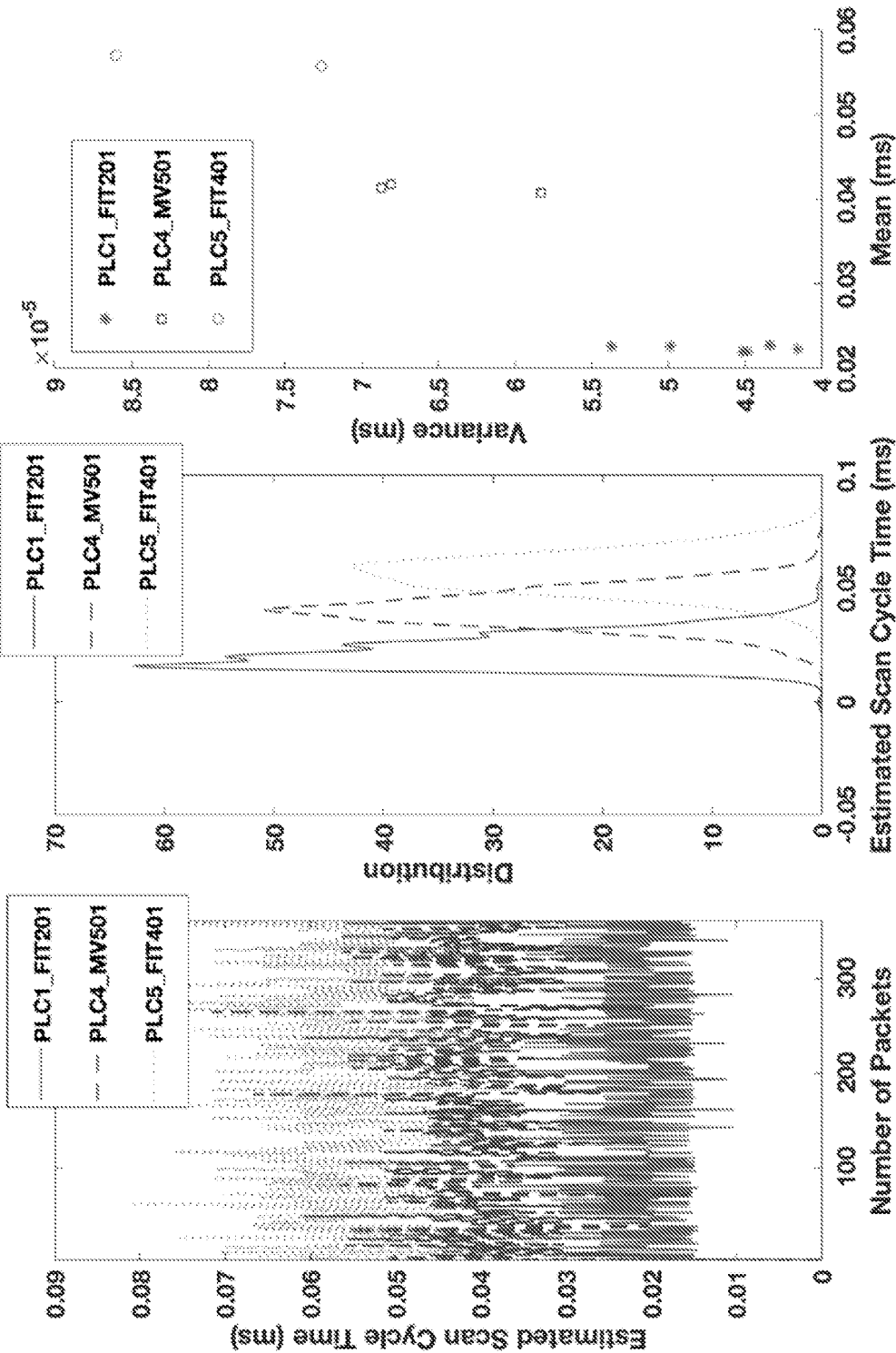


FIG. 12

Table 3

Chunk Size	10	30	60	100	120	150	200
Accuracy	59.8854%	82.4561%	87.2727%	93.5484%	96.1538%	90.4762%	92.8571%

FIG. 13**Table 4**

k-fold	2	3	5	10	15	20
Accuracy	88.2883%	85.5856%	89.1892%	88.2883%	89.6396%	90.0901%

FIG. 14**Table 5**

	PLC 1	PLC 2	PLC 3	PLC 4	PLC 5	PLC 6
Stable ^a	99.03%	100%	84.47%	87.38%	100%	92.23%
Scale ^b	94.44%	97.22%	93.33%	96.43%	94.44%	93.33%

^aStability under temperature variation, scalability using 2-class classifier

^bScalability using the one class classifier approach

FIG. 15

Table 6

	PLC 1	PLC 2	PLC 3	PLC 4	PLC 5	PLC 6	Accuracy
DF (ms)	22.31	34.07	39.71	41.08	56.78	25.82	93.54
MF (ms)	22.15	34.32	39.81	44.58	57.12	25.36	99.06%

FIG. 16**Table 7**

Device Type	Identification Accuracy
4 x Siemen IEDs	82.2148%
4 x Wago PLCs	70.0909%

FIG. 17**Table 8**

Attack Type	PLC 1	PLC 2	PLC 3	PLC 5	PLC 6
MiTM: TPR	100%	100%	100%	100%	100%
MiTM: FNR	0%	0%	0%	0%	0%
MN TPR:	100%	100%	100%	100%	100%
MN FNR	0%	0%	0%	0%	0%
MPDK TPR:	100%	100%	22%	100%	100%
MPDK FNR:	0%	0%	78%	0%	0%
MFDK TPR:	0%	82.35%	0%	100%	100%
MFDK FNR:	100%	17.64%	100%	0%	0%

FIG. 18

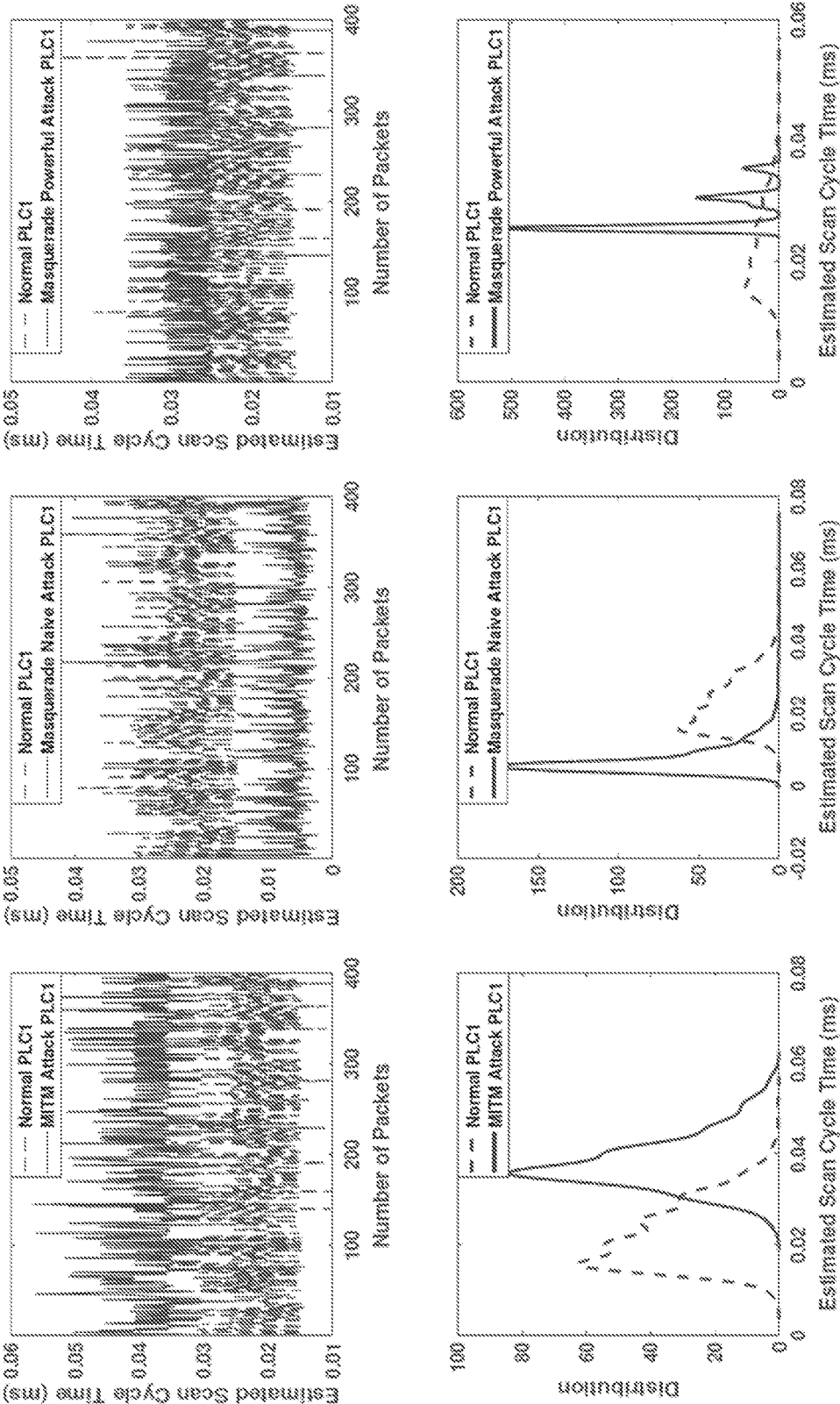


FIG. 19

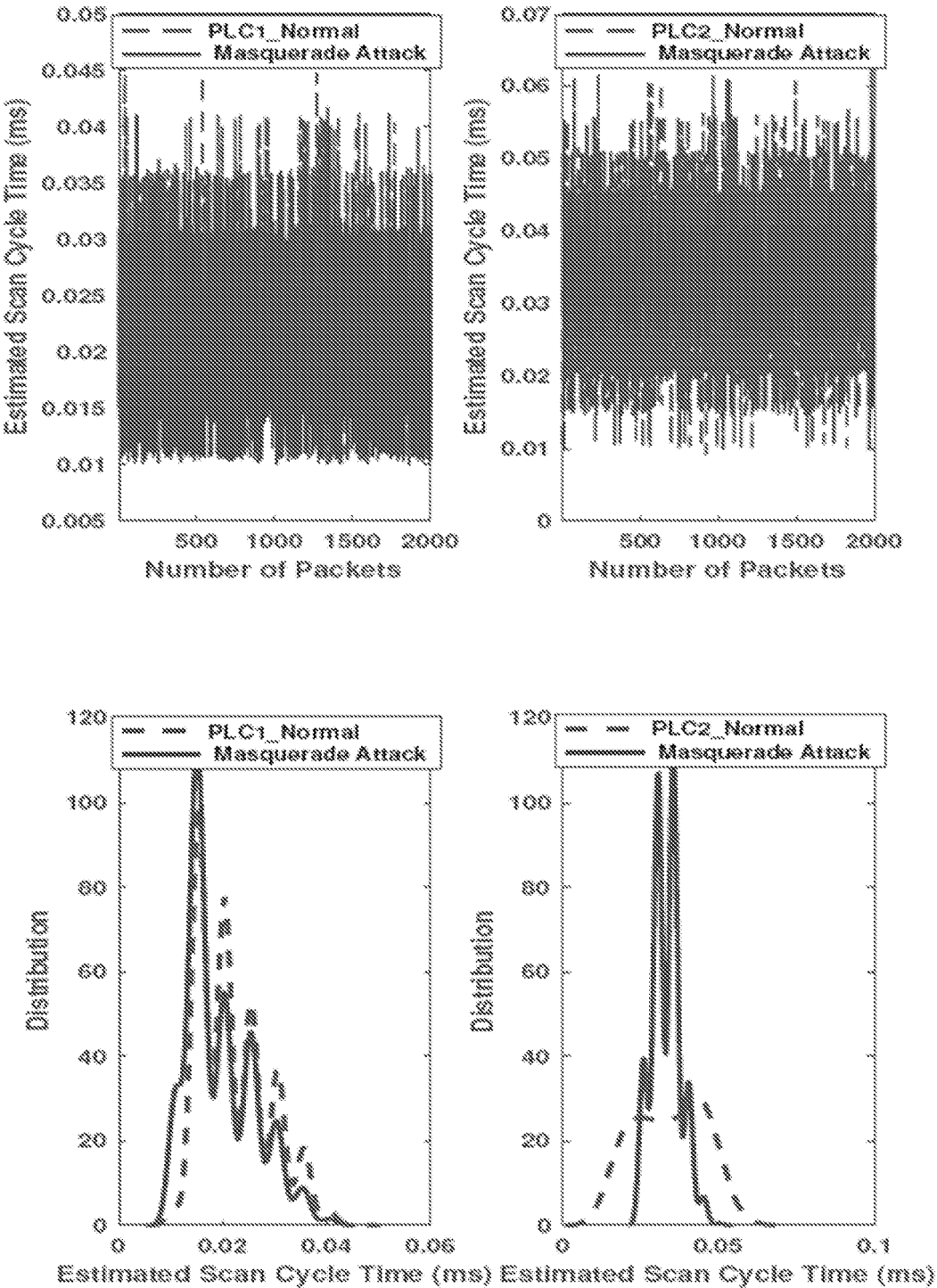


FIG. 20A

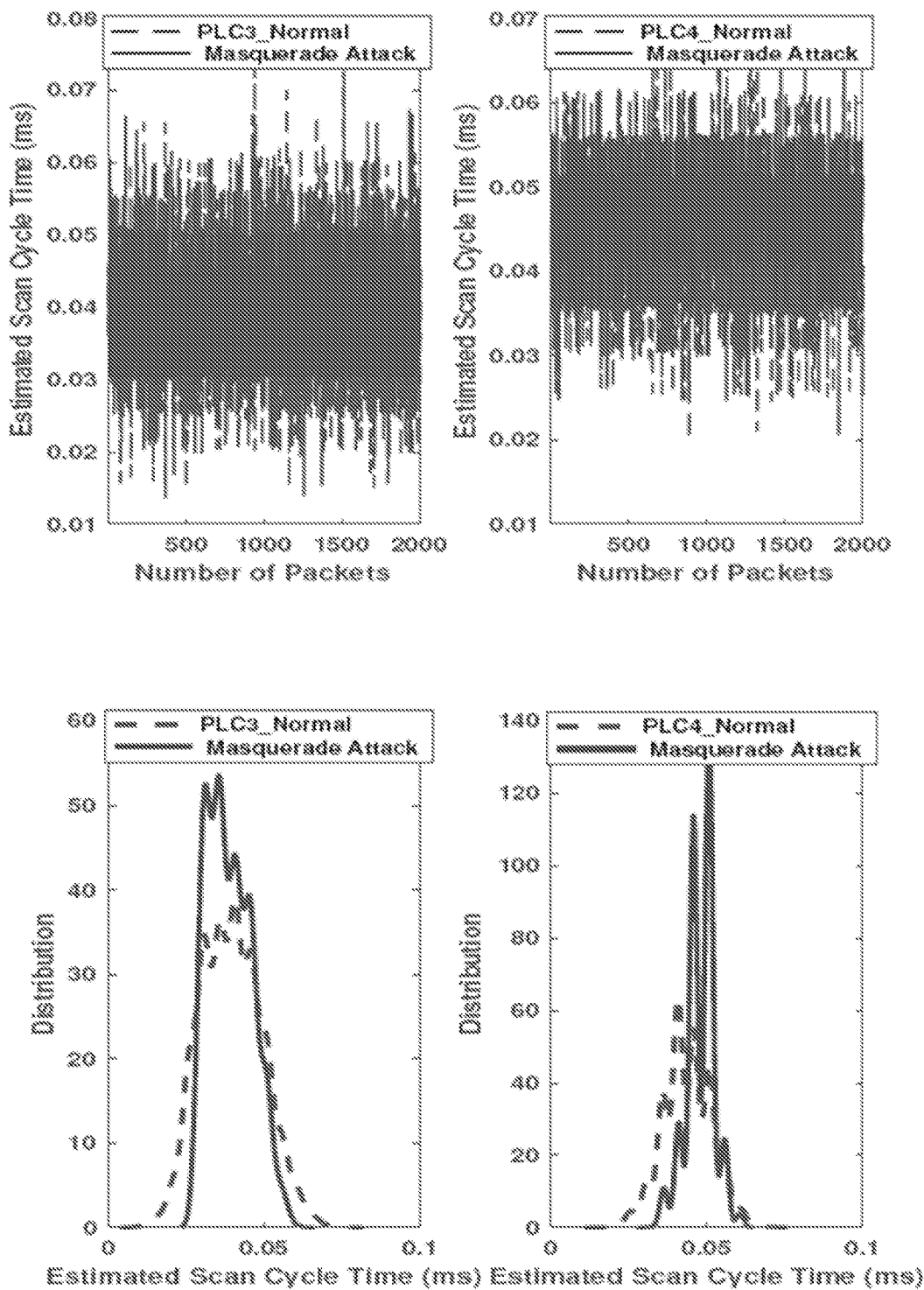


FIG. 20B

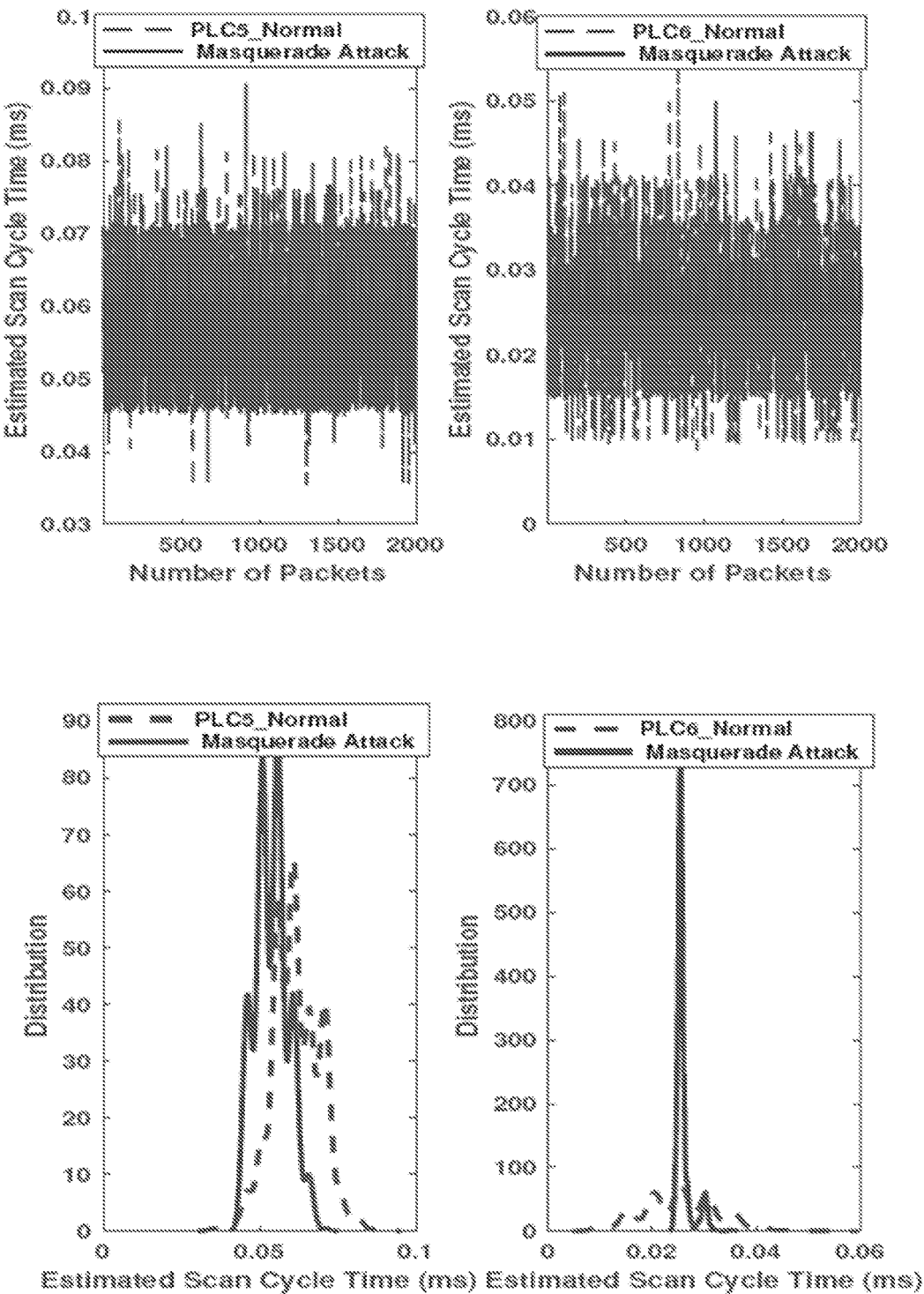


FIG. 20C

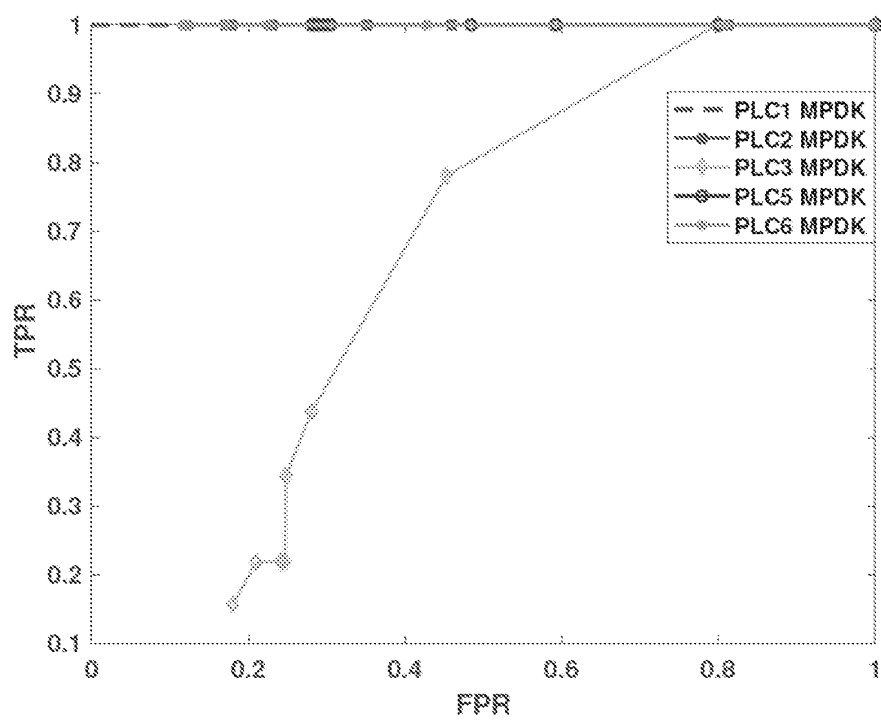


FIG. 21

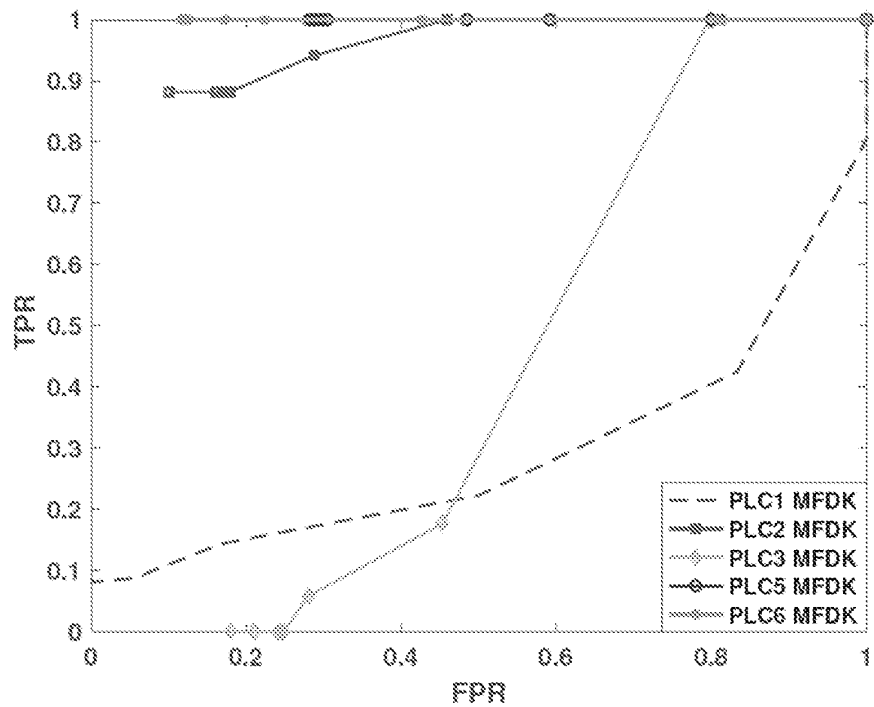


FIG. 22

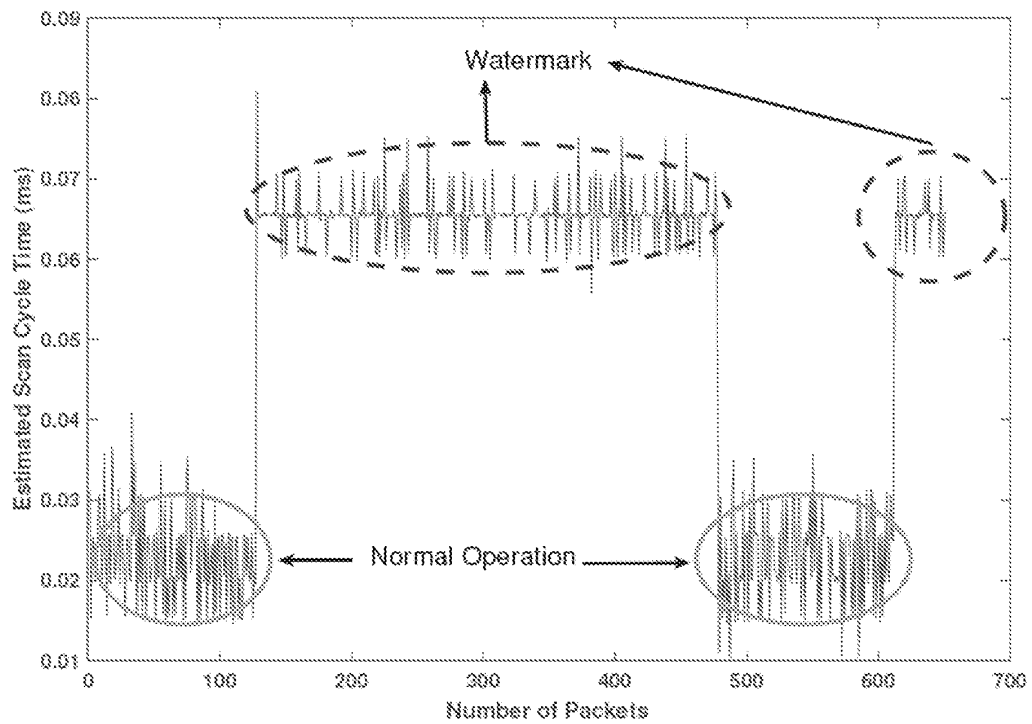


FIG. 23

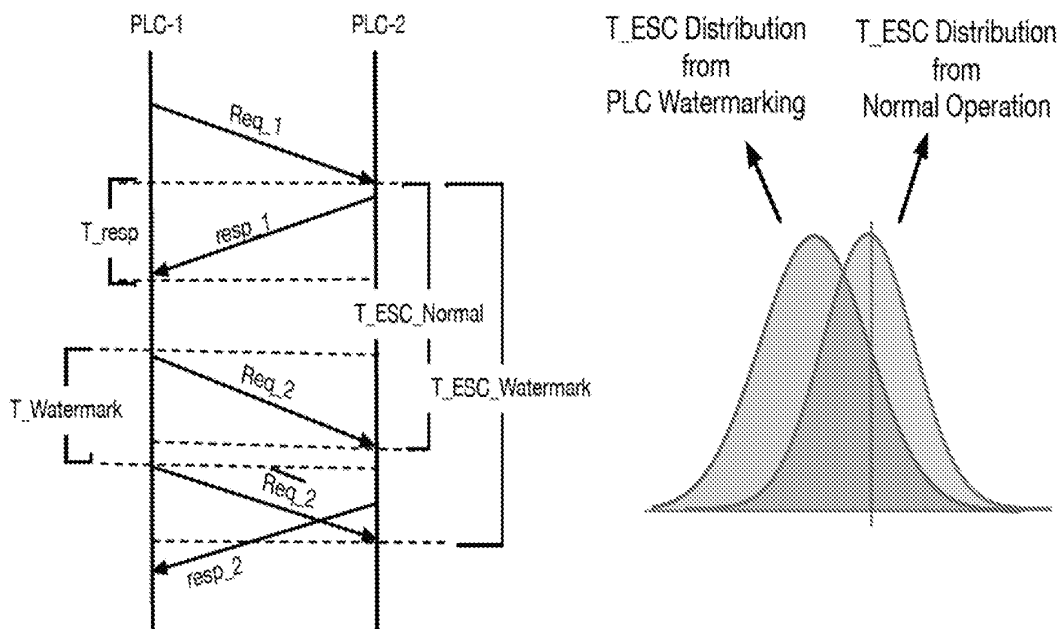


FIG. 24

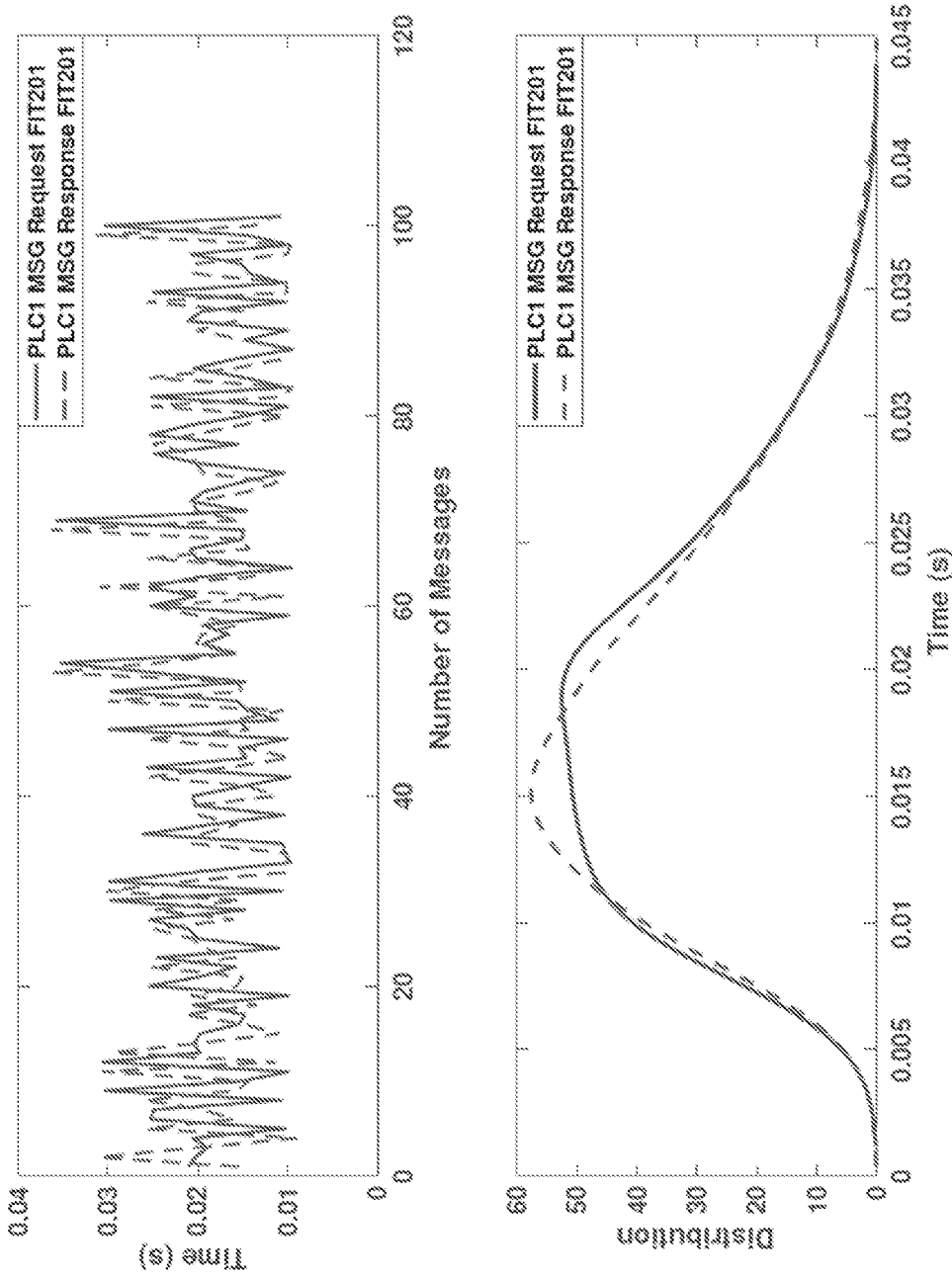


FIG. 25

Table 9

Size	10	30	60	120	250	500	1000
TNR	95.57%	99.49%	100%	100%	100%	100%	100%
FPR	4.43%	0.50%	0%	0%	0%	0%	0%

FIG. 26**Table 10**

WM Type	No-WM	20 ms delay	40 ms delay	Rand
TNR	100%	91.84%	84.62%	98.33%
FPR	0%	8.16%	15.38%	1.67%

FIG. 28**Table 11**

Attack / PLC	PLC 1	PLC 2	PLC 3	PLC 4	PLC 5	PLC 6
Replay: TPR	95%	97.78%	82.05%	100%	100%	98.21%
Replay: FNR	5%	2.22%	17.95%	0%	0%	1.79%
MFDK: TPR	88.24%	100%	81.25%	100%	100%	100%
MFDK: FNR	11.76%	0%	18.75%	0%	0%	0%

FIG. 31

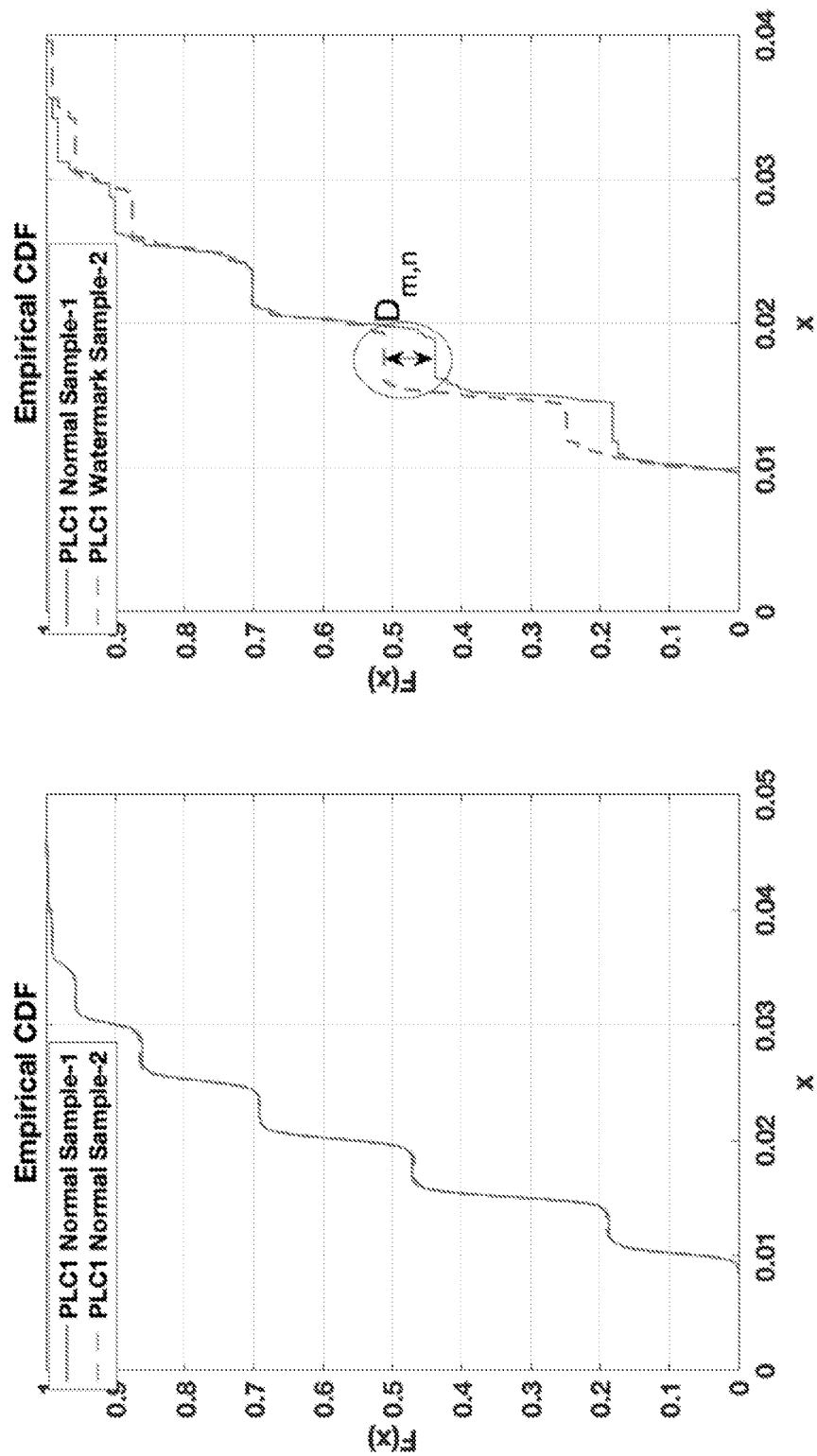


FIG. 27

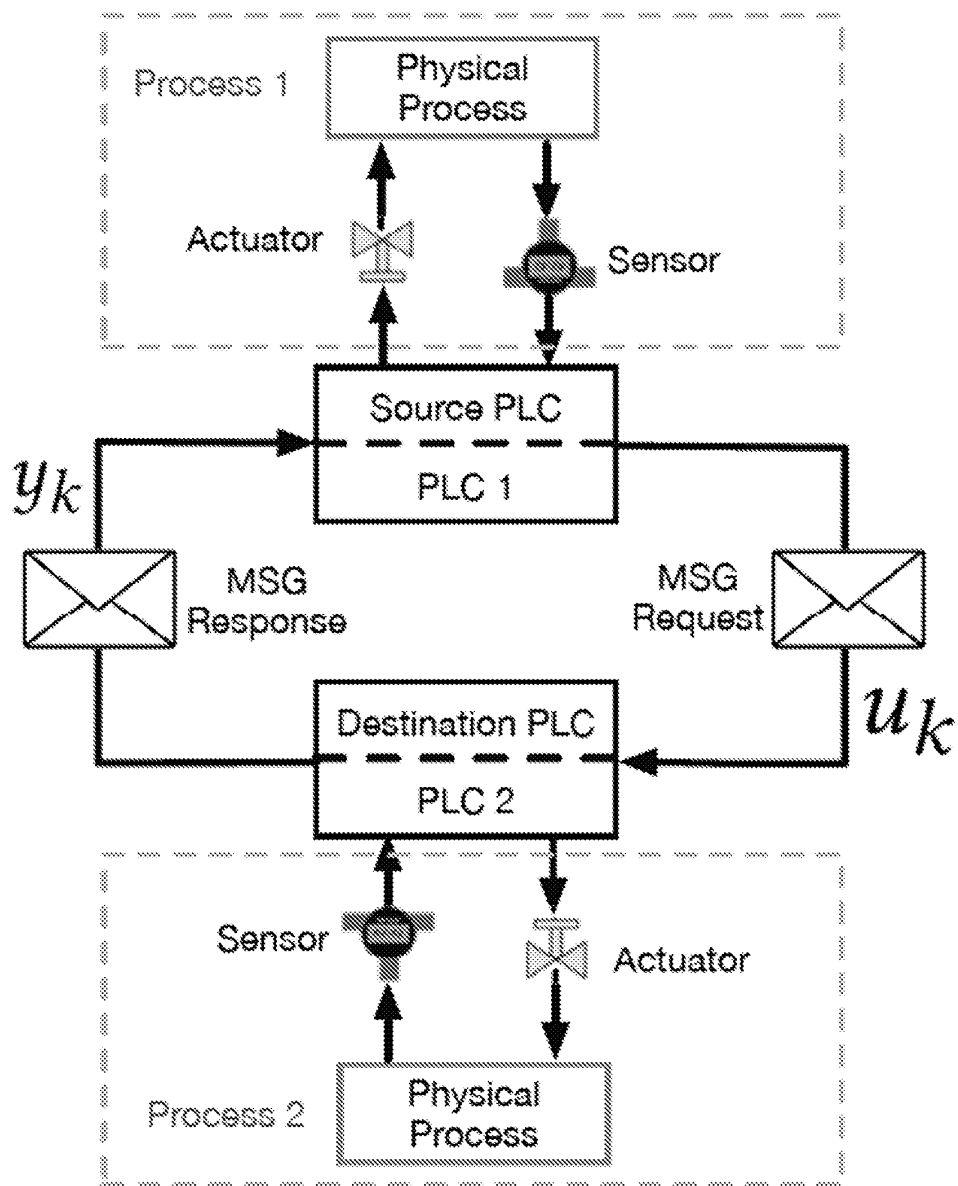


FIG. 29

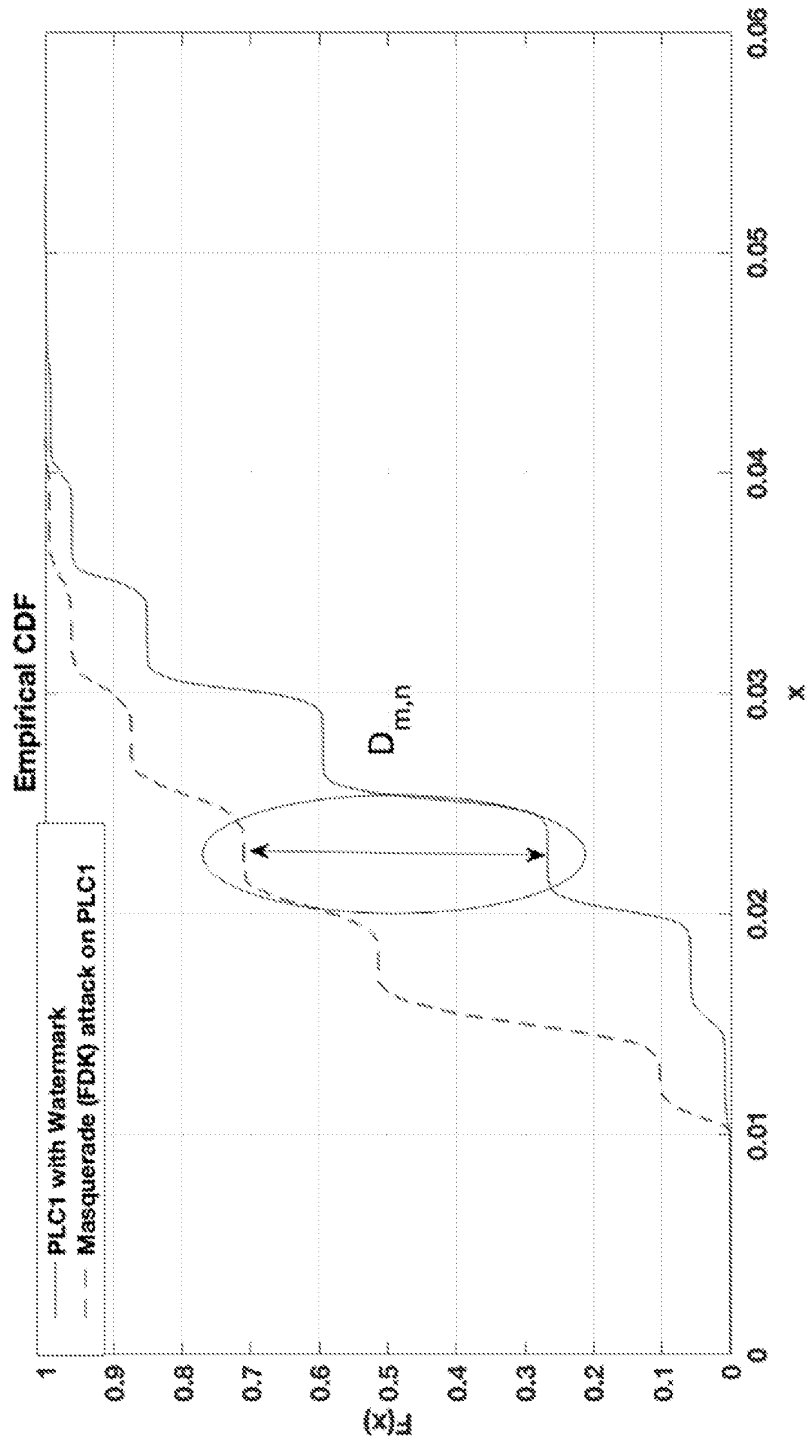


FIG. 30

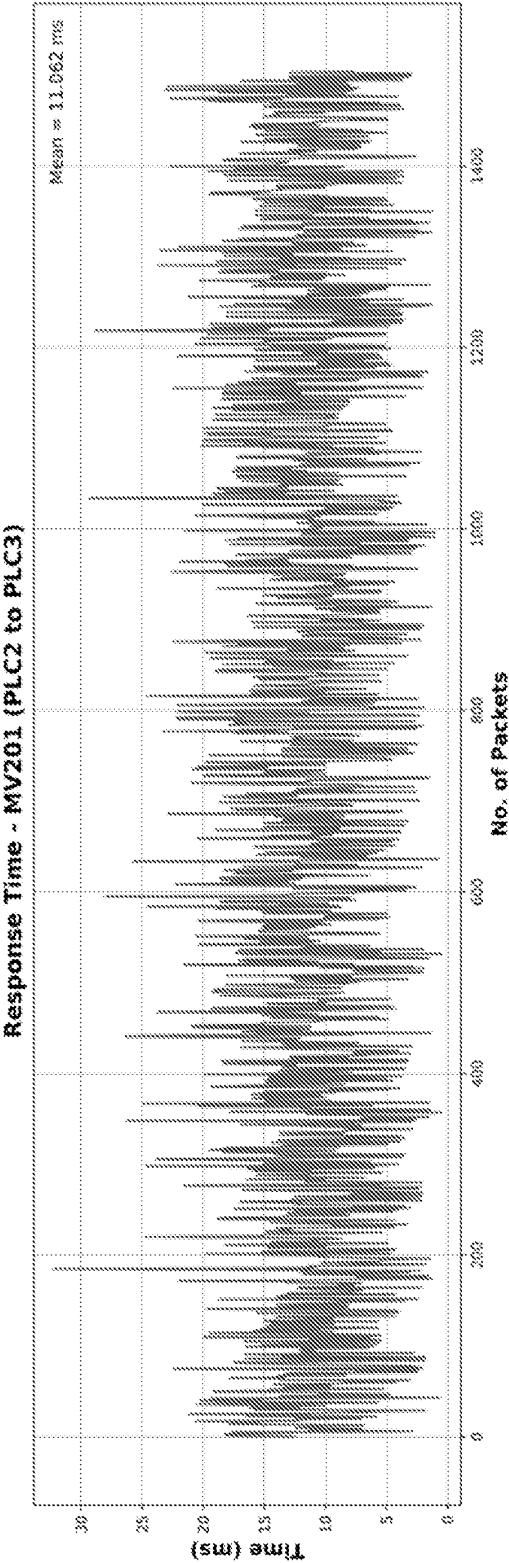


FIG. 32

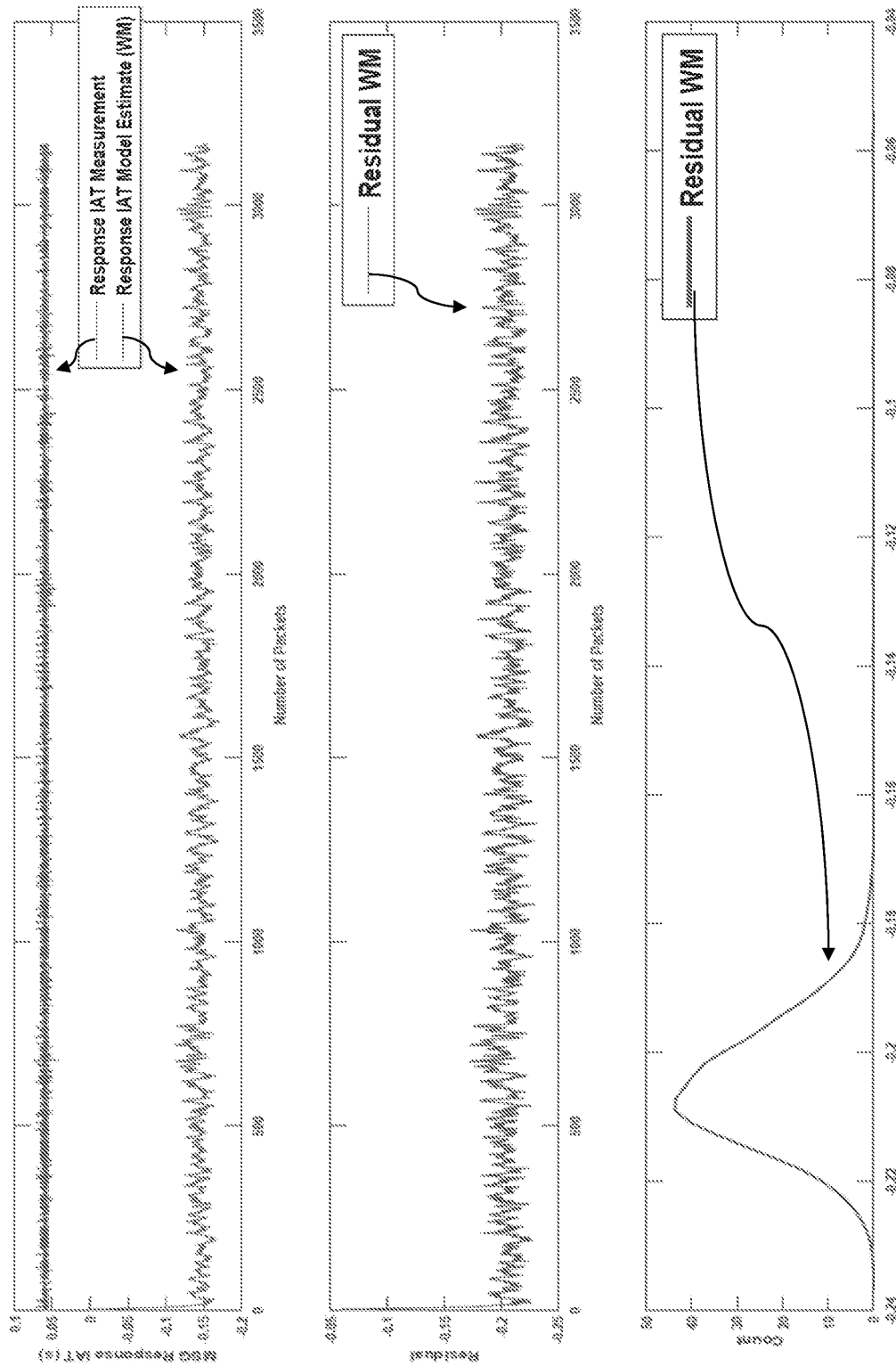


FIG. 33

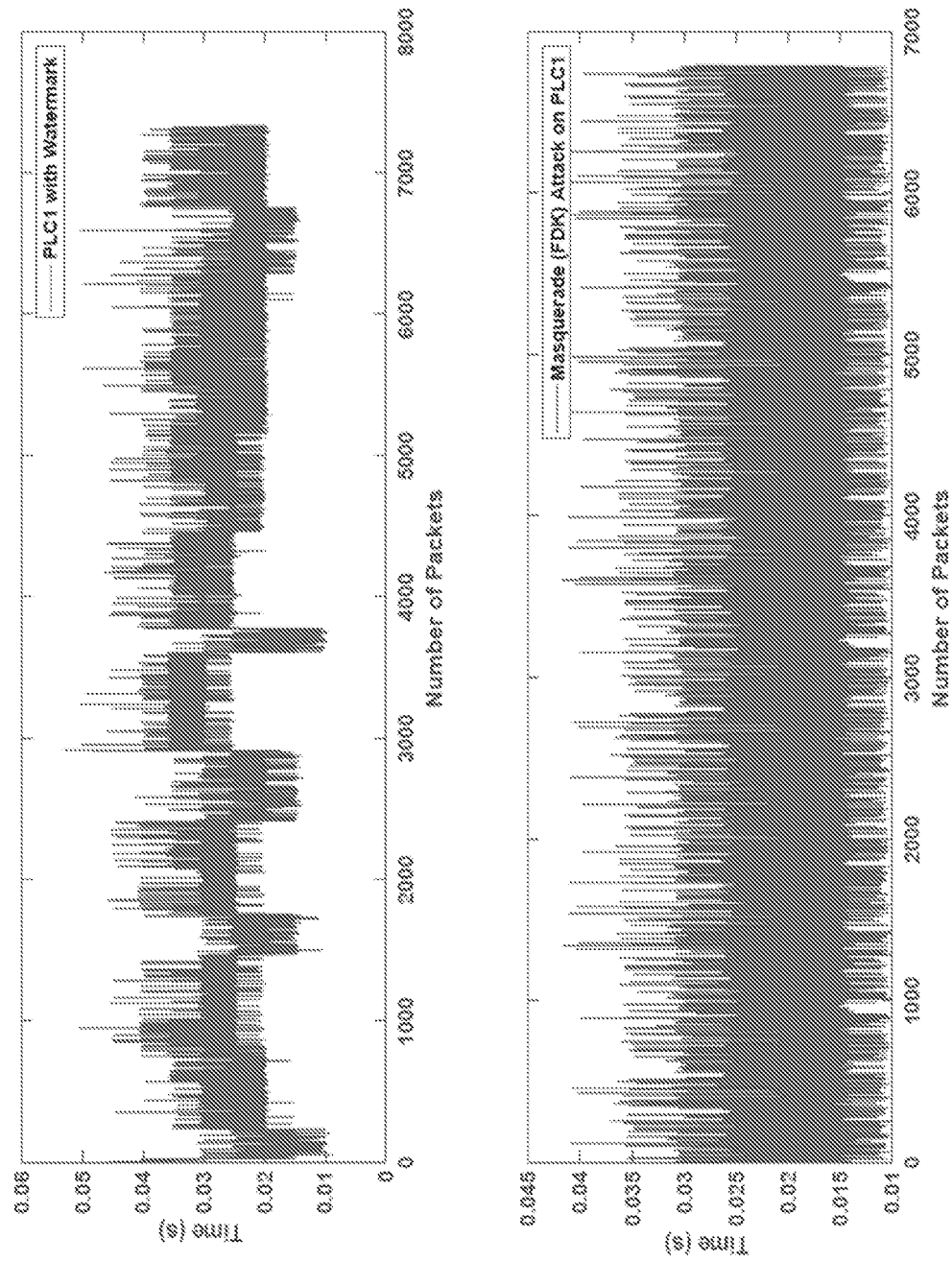


FIG. 34