

Source Traffic Modeling in Wireless Sensor Networks for Target Tracking

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Traffic within WSN – How much do we know about it?

- *A fact.*
 - too much talk about traffic in WSN, but too few understanding about it.
- *Why?*
 - The specialty of WSN renders the existing insights on traditional network traffic less useful.
 - Because traffic in WSN is highly application dependent, and people do not know where to start.

Traffic scenario categorization for WSN

- Periodically reporting
 - HELLO message, routing message exchange
 - Applications like temperature monitoring, video surveillance system
- Event-driven transmission
 - Reporting any feature with 0-1 outcome
 - Applications like target tracking, where the detection of the target is an interesting event

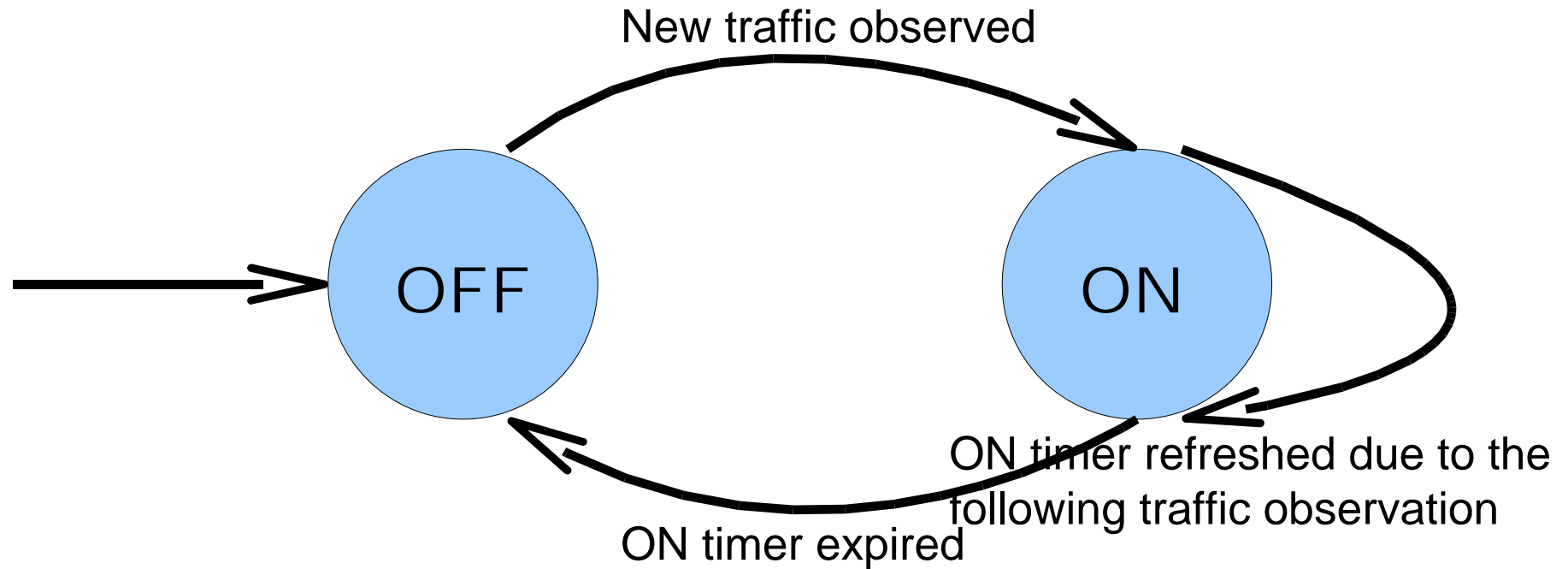
Traffic modeling for WSN

- Periodically reporting
 - Constant Bit Rate (CBR)

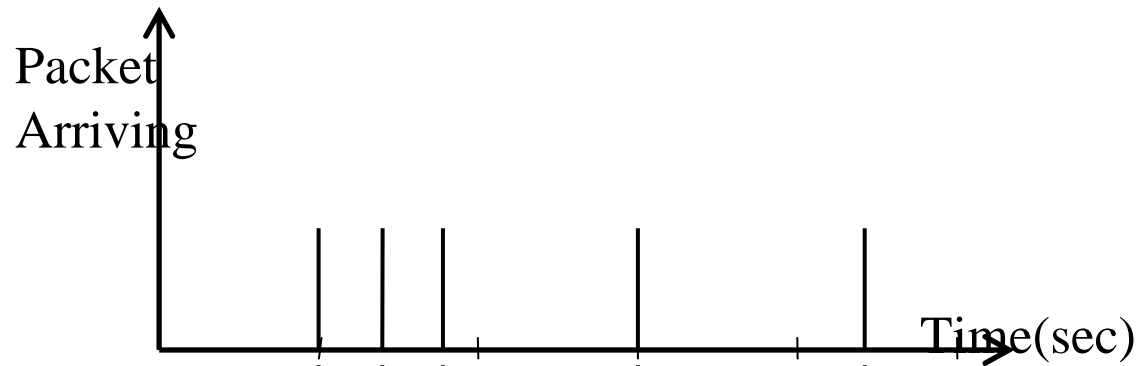
- Event-driven transmission
 - Poisson?
 - Bursty traffic

ON/OFF model

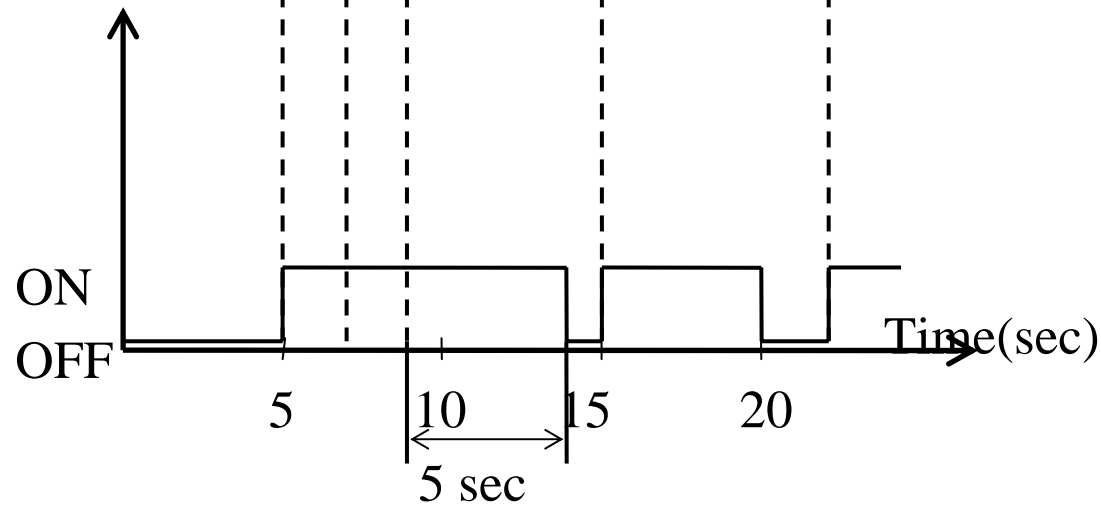
– state transition diagram



ON/OFF Model – a paradigm



ON timer length: 5 sec



An event-driven scenario

– WSN for target tracking

- Targets move around in the WSN deployment area
- Target is detected when it enters into the nearby region of a sensor node
- Traffic burst arises from a sensor node when a concerned target stays in its sensing range
- The time duration for a traffic burst corresponds to an ON period in the ON/OFF model

Traffic modeling

– WSN for target tracking

- Goal:
 - in order to give insights about traffic characters in event-driven WSN scenarios
- Methods:
 - By carrying simulations in a modified ns-2 (<http://apachepersonal.miun.se/~qinwan/resources.htm>)
 - Capturing traffic bursts using ON/OFF model
 - Fitting ON/OFF period distributions to get insights

Traffic modeling

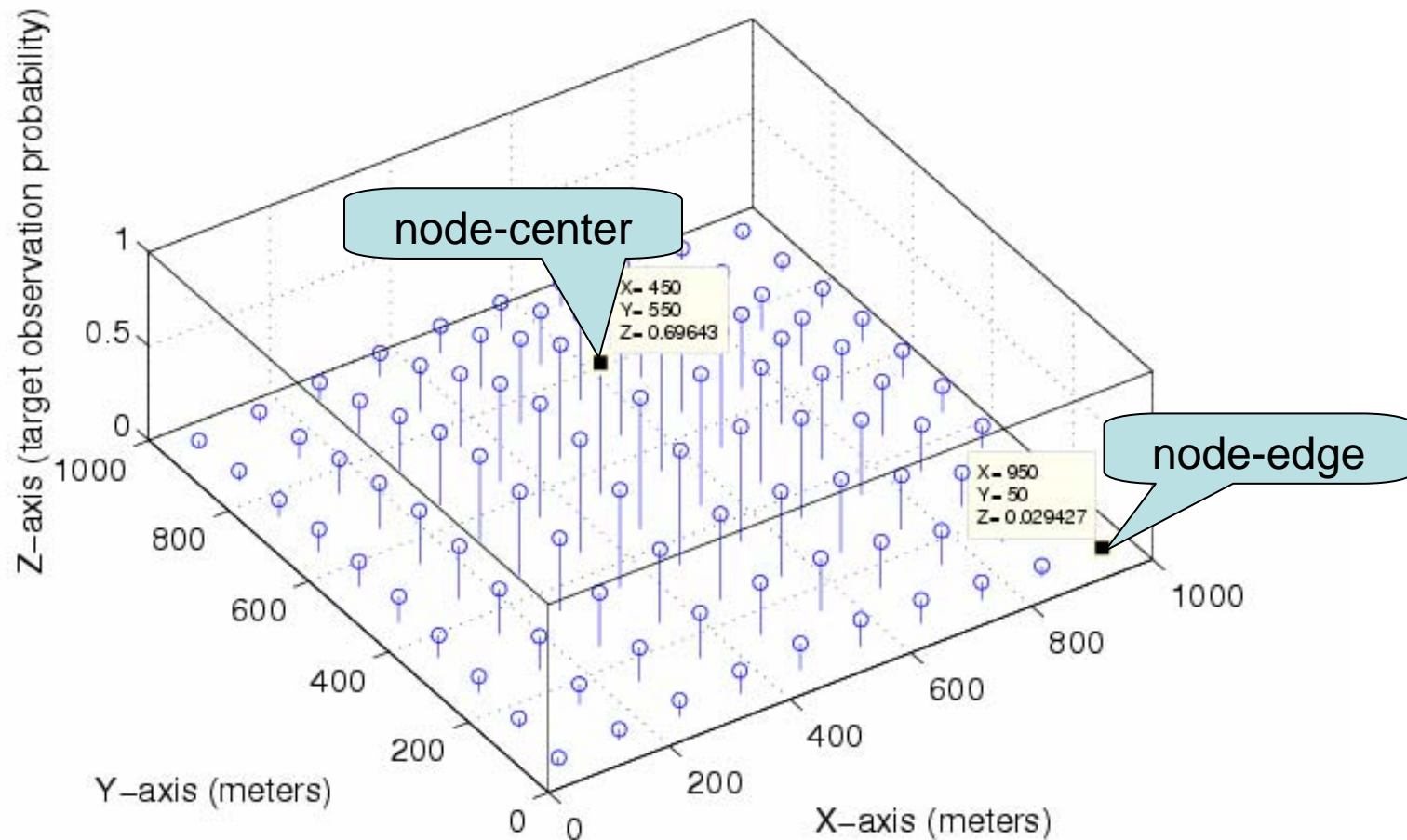
– WSN for target tracking

- Simulation settings:
 - Nodes number: 100
 - Deployment area: 1000m×1000m
 - One sink: located in the center
 - One target: randomly moving around
 - Sensing range: ~250m
 - Communication range: ~250m
 - Routing: multi-hop AODV protocol

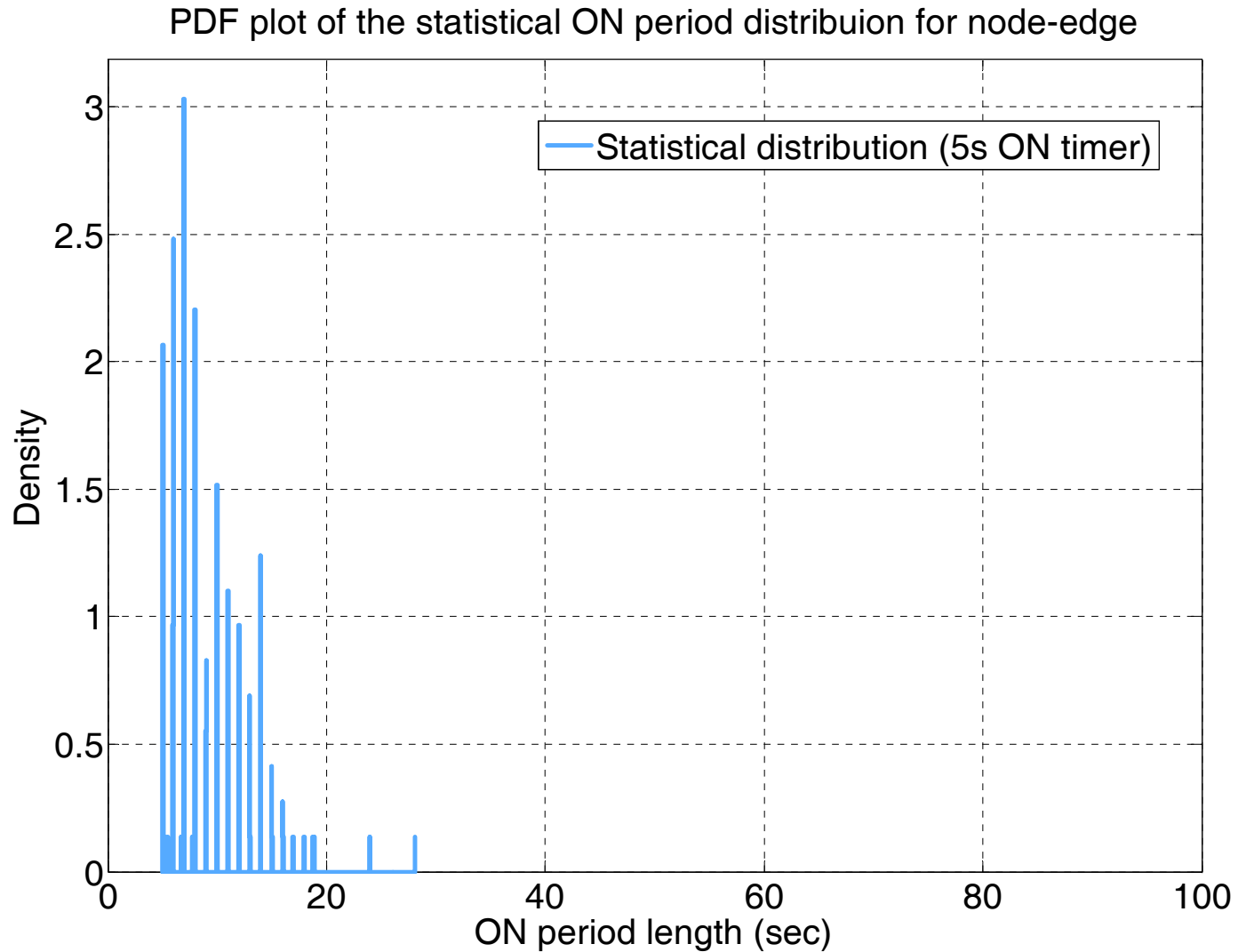
Traffic modeling

- WSN for target tracking

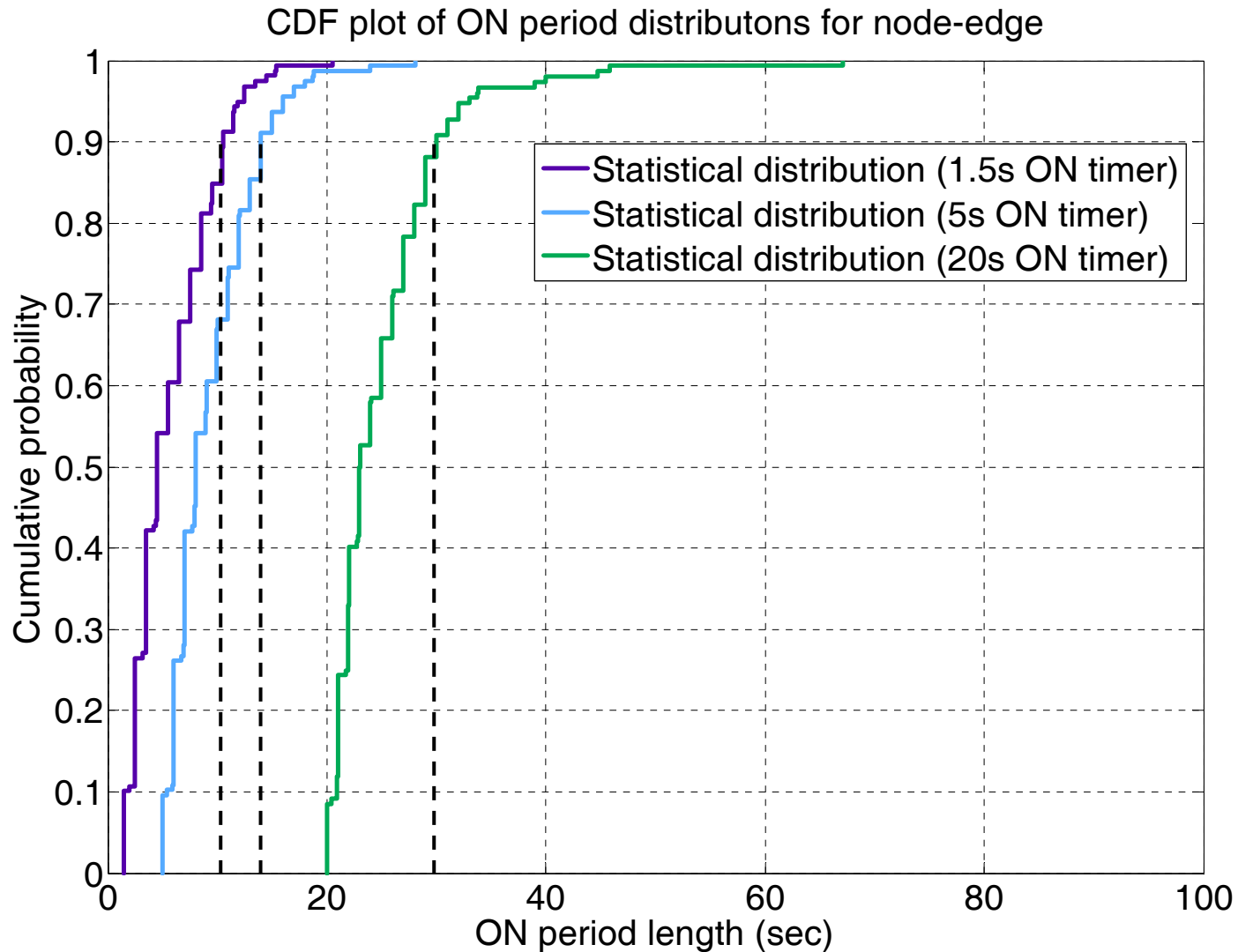
Distribution of target observation probability:



Results – ON period distribution

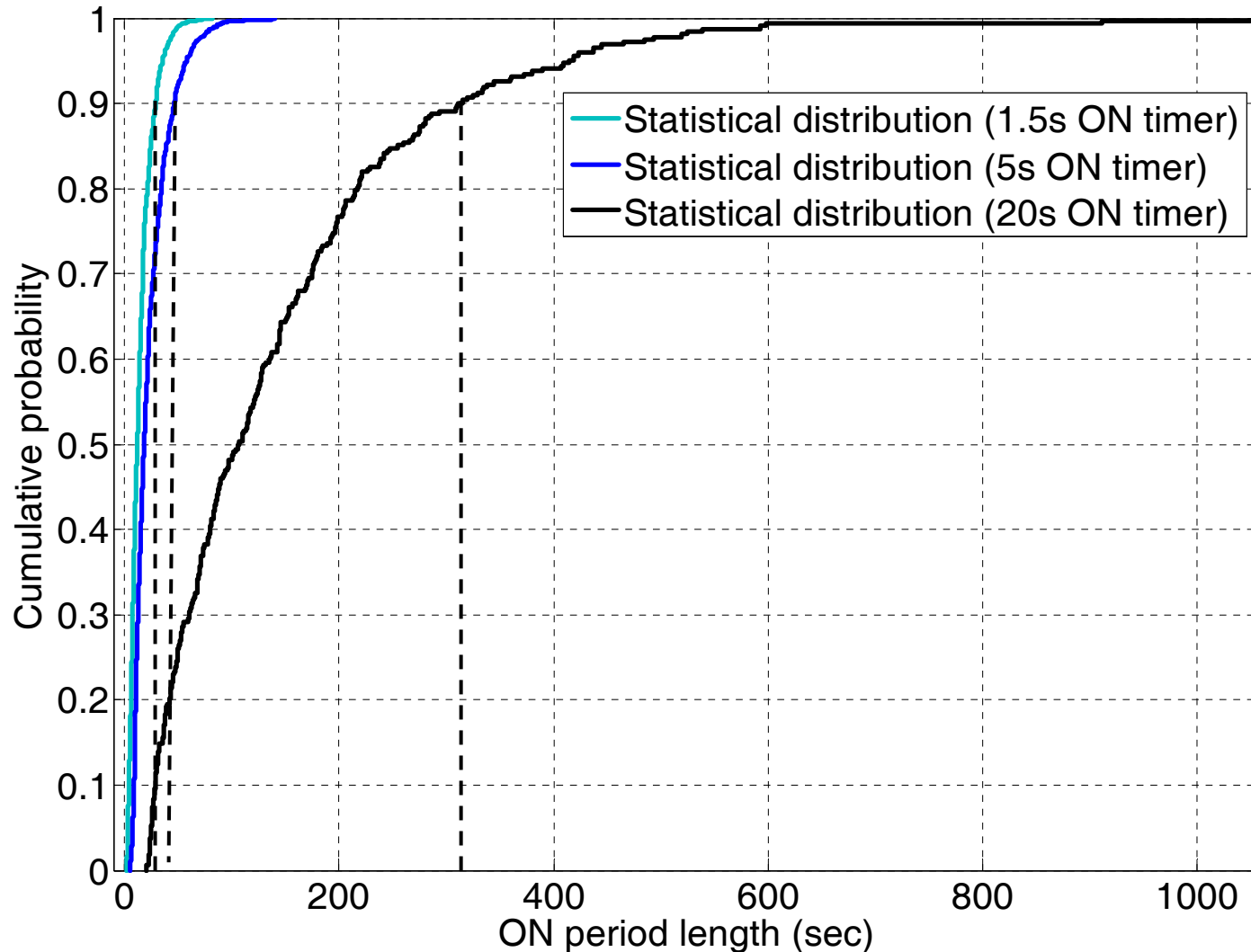


Results – ON period distribution

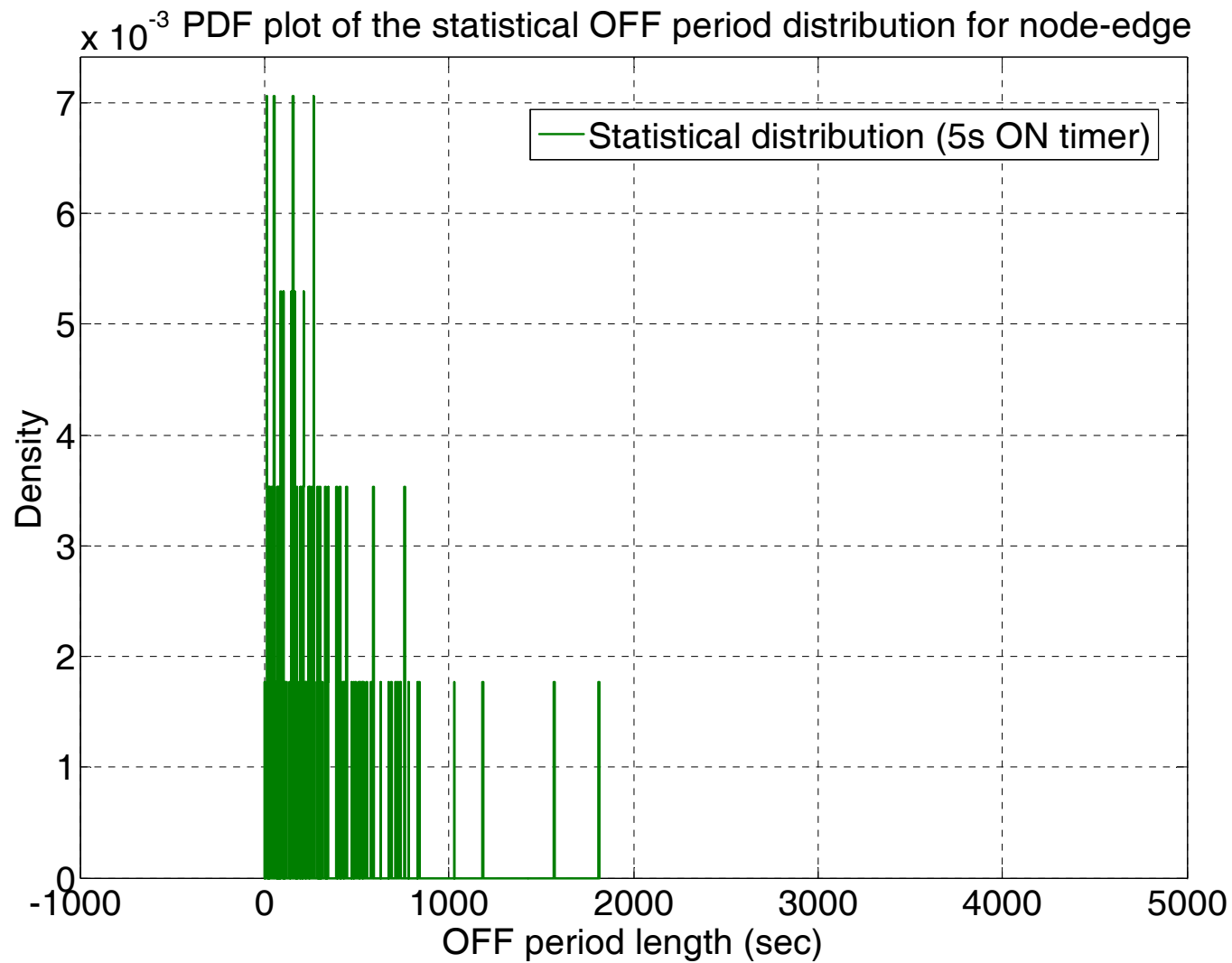


Results – ON period distribution

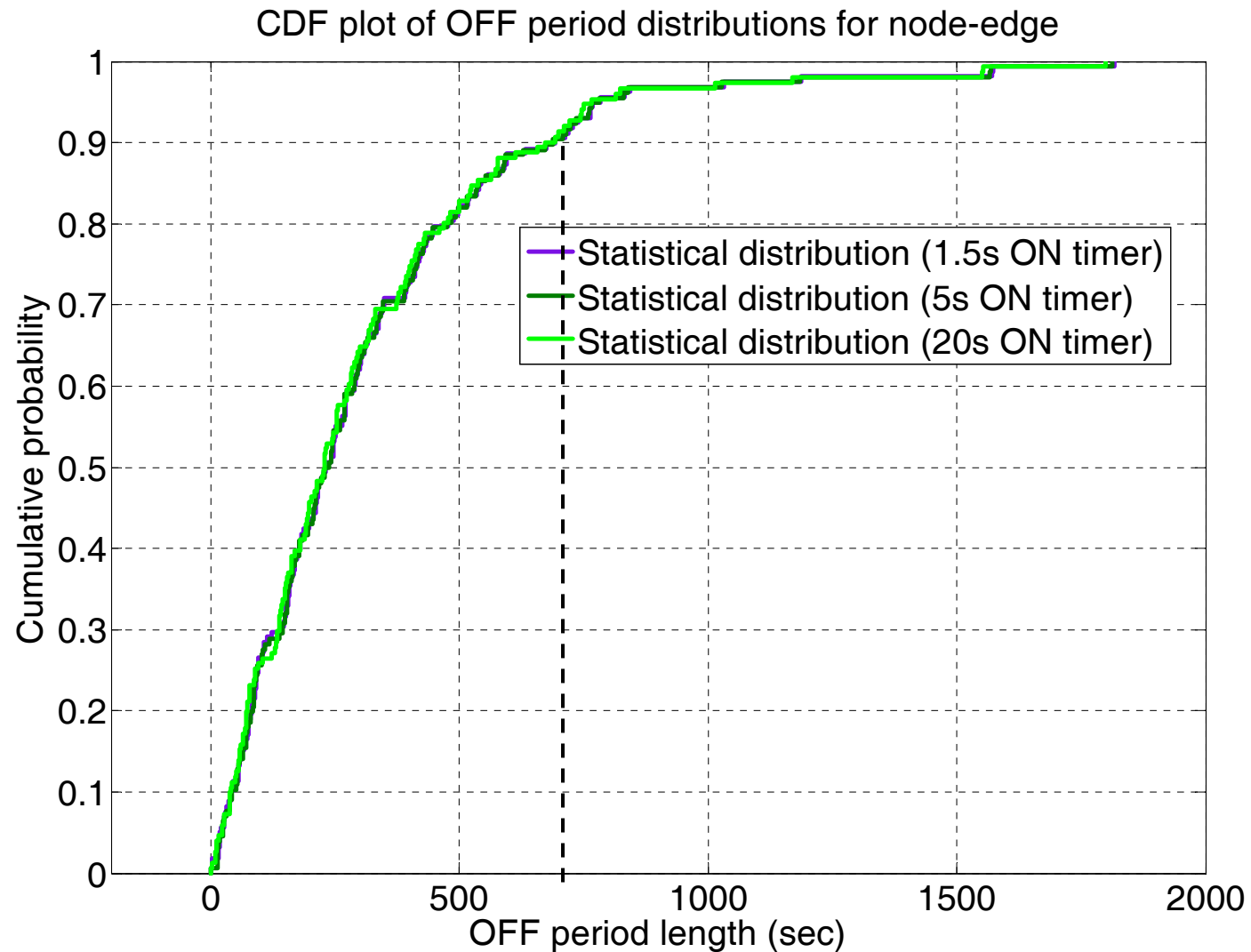
CDF plot of ON period distributions for node-center



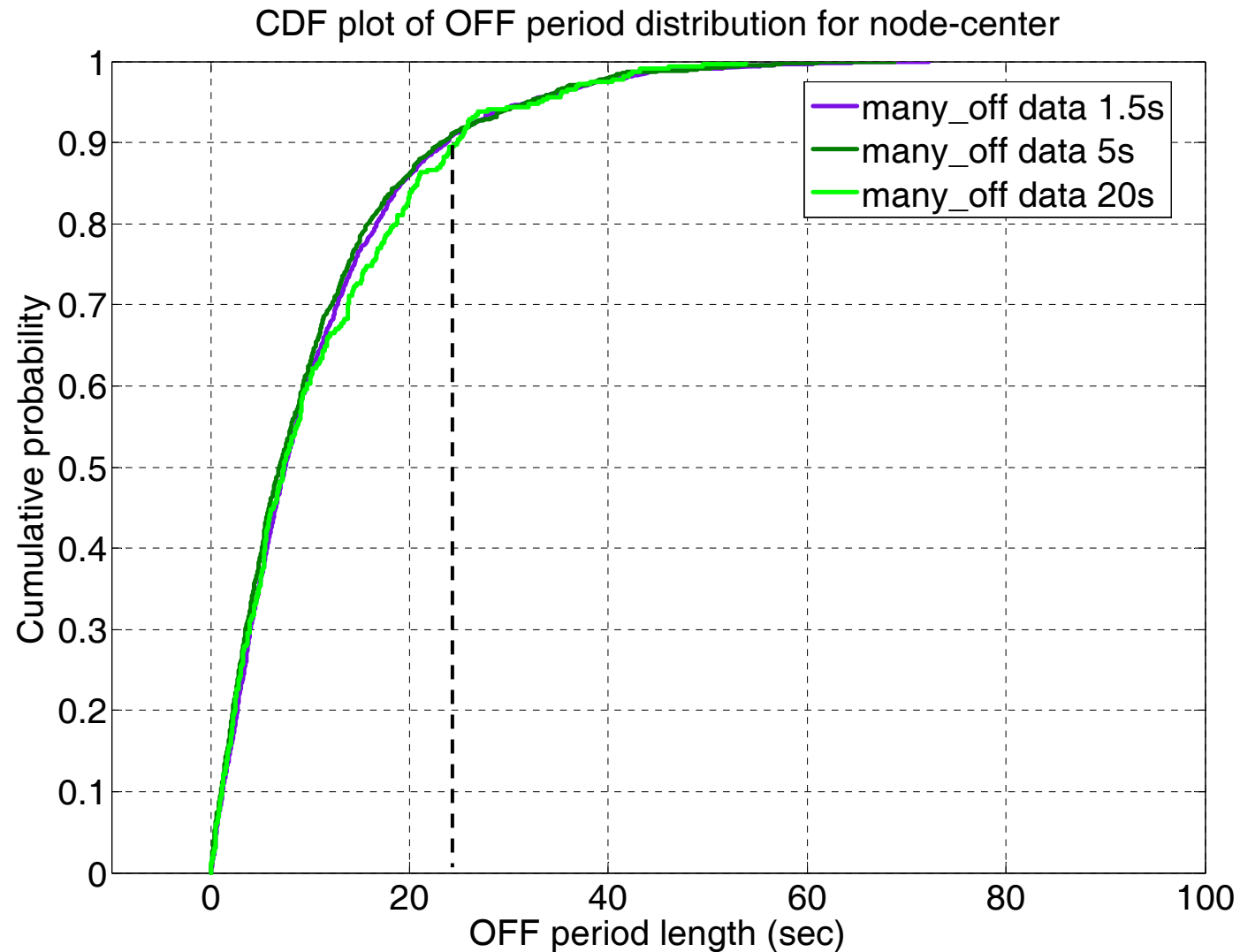
Results – OFF period distribution



Results – OFF period distribution



Results – OFF period distribution



ON/OFF period distribution fitting

- Generalized Pareto distribution
 - Probability density function:

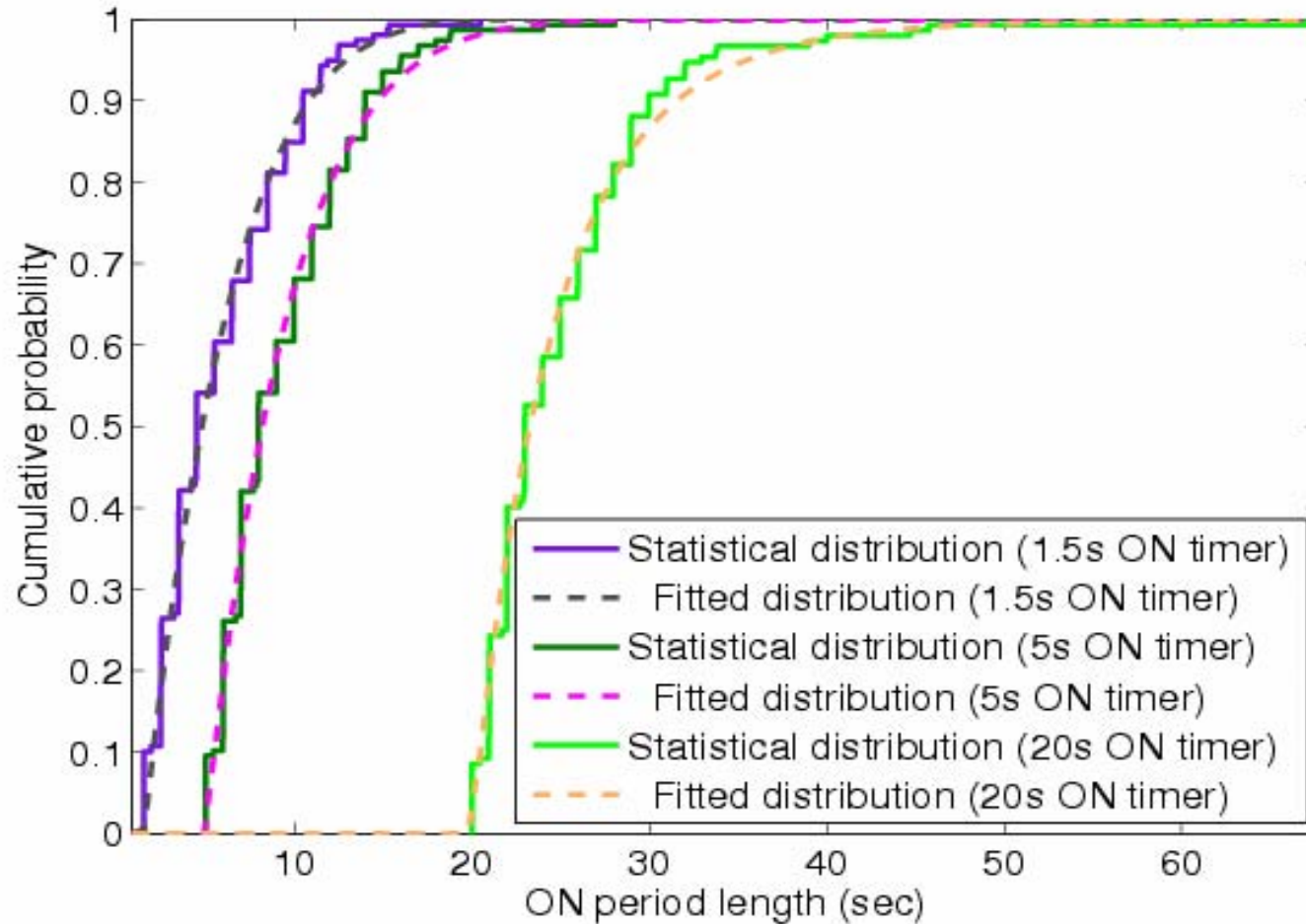
$$y = f(x | k, \sigma, \theta) = \left(\frac{1}{\sigma} \right) \left(1 + k \frac{(x - \theta)}{\sigma} \right)^{-1 - \frac{1}{k}}, \quad \theta < x$$

- Useful property:

$$\theta < x < -\frac{\sigma}{k} \text{ (short tail), if } k < 0$$

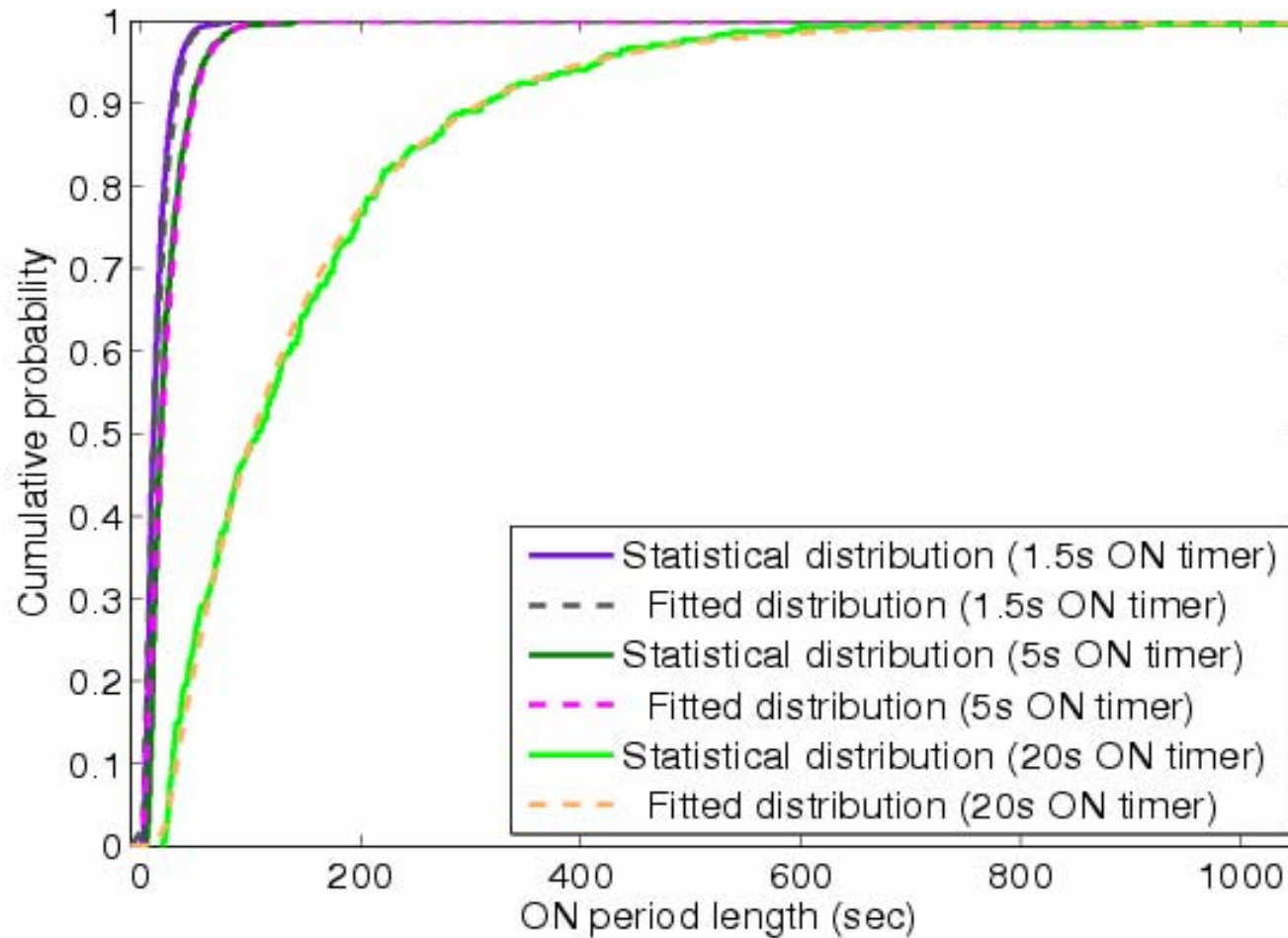
ON/OFF period distribution fitting

Fitted ON period distribution for node-edge



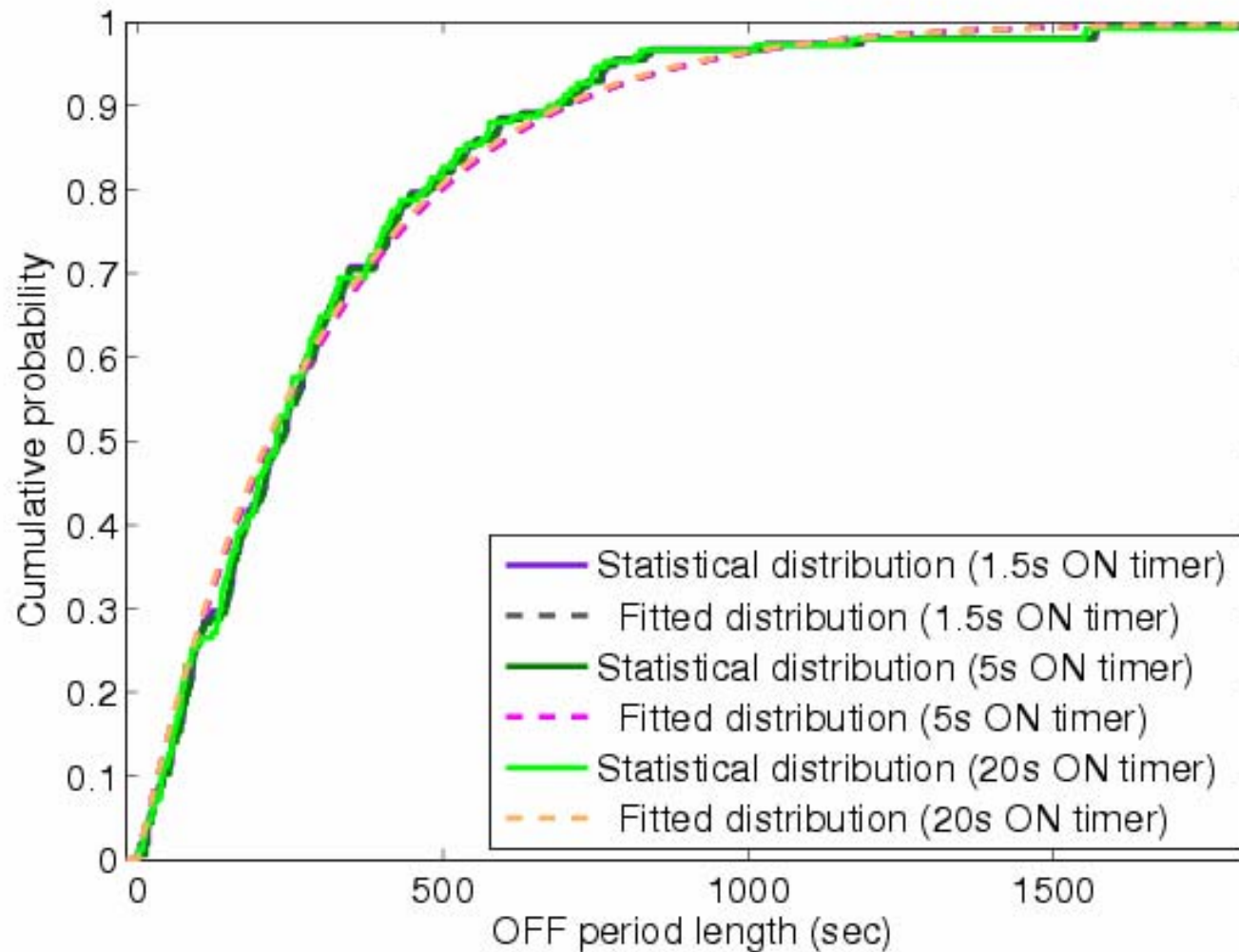
ON/OFF period distribution fitting

Fitted ON period distribution for node-center



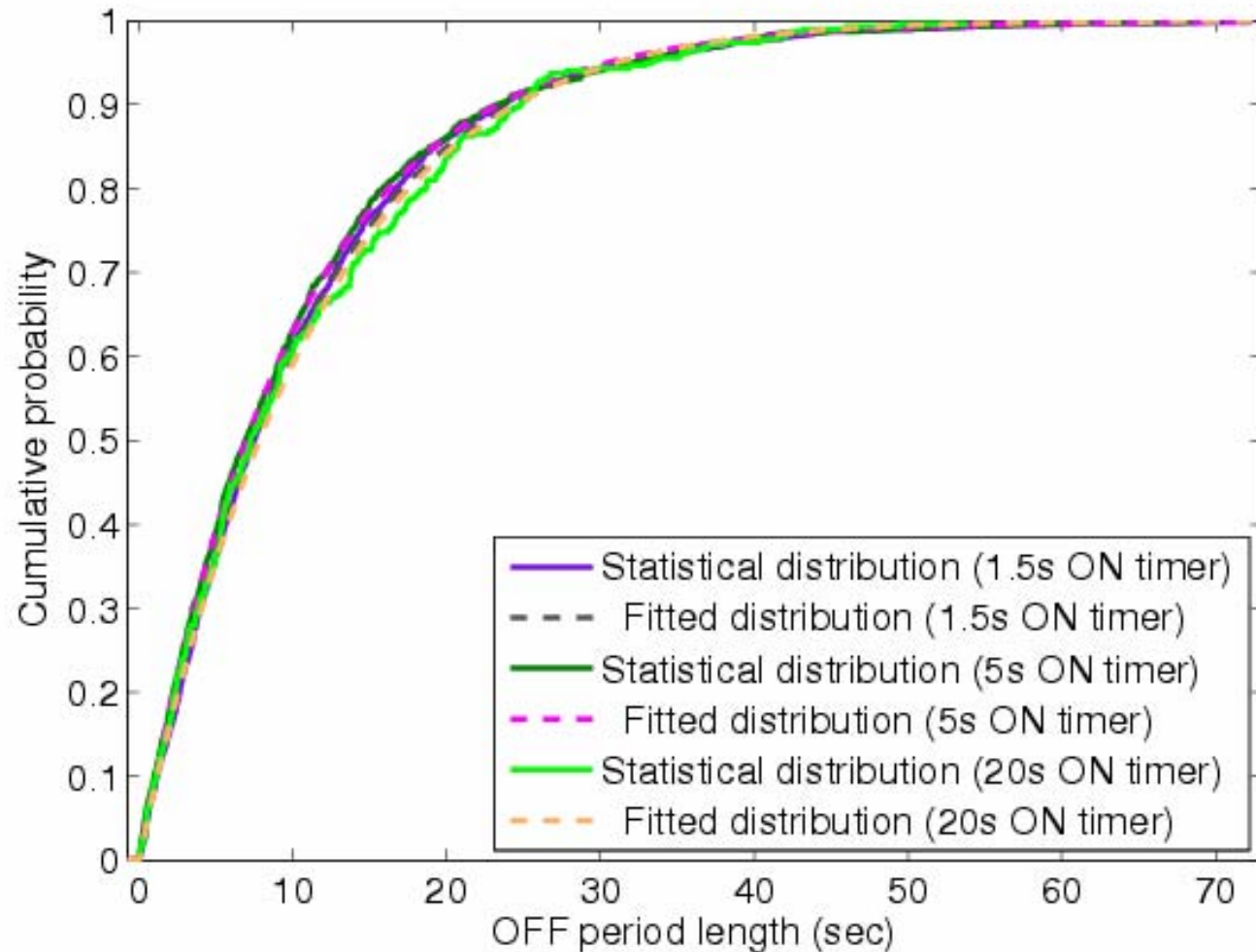
ON/OFF period distribution fitting

Fitted OFF period distribution for node-edge



ON/OFF period distribution fitting

Fitted OFF period distribution for node-center



Parameters used in fitting ON/OFF period distributions with GPD

	Fitted ON period distribution						Fitted OFF period distribution					
nodes	<i>node-edge</i>			<i>node-center</i>			<i>node-edge</i>			<i>node-center</i>		
ON timer	1.5s	5s	20s	1.5s	5s	20s	1.5s	5s	20s	1.5s	5s	20s
k	-0.20	-0.11	0.08	-0.15	-0.06	0.07	-0.03	0.03	-0.02	-0.03	0.01	-0.07
σ	5.05	4.77	4.57	4.80	19.65	11.56	317.1	317.9	308.9	15.00	10.03	11.56
θ (sec.)	1.49	4.99	19.99	1.49	4.99	19.99	0.001	0.001	0.001	0.001	0.001	0.001
$x F(Period \leq x) = 0.99$ (sec.)	16.7	22.3	45.5	51	84	654	1356	1355	1353	46.8	47.2	45.2
Mean (sec.)	5.703	9.291	24.96	14.39	23.53	144	307.0	307.4	302.2	10.55	10.12	10.77
$\frac{x}{Mean}$	2.93	2.40	1.82	3.54	3.57	4.53	4.42	4.41	4.48	4.44	4.67	4.20

$k < 0$

$k < 0$

$k < 0$

$k < 0$

Short-tail property

$x < 5$
Mean

Why “short-tail property” is good?

- If traffic exhibits “short-tail property”, an observed unusually long ON period may indicate an energy exhaustion attack
- If traffic exhibits “short-tail property”, an observed unusually long OFF period can indicate a node failure
- With “short-tail property”, we can identify these abnormal periods with high confidence at early time (*by waiting less than 5 times of the mean period duration in the above scenario*).

Conclusions

- We present a traffic modeling for an event-driven sensor network scenario – target tracking
- ON/OFF model is found to be suitable for capturing the bursty nature of event-driven sensing traffic
- The statistical distributions of ON and OFF periods are found to follow the *generalized Pareto distribution* very well
- The OFF period distribution is found to be insensitive to the choice of ON timer, which could be some kind of self-similarity.
- Both ON and OFF period distributions exhibit “short-tail property”, which means the abnormal ON/OFF period can be identified quickly.

Thank you!