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.

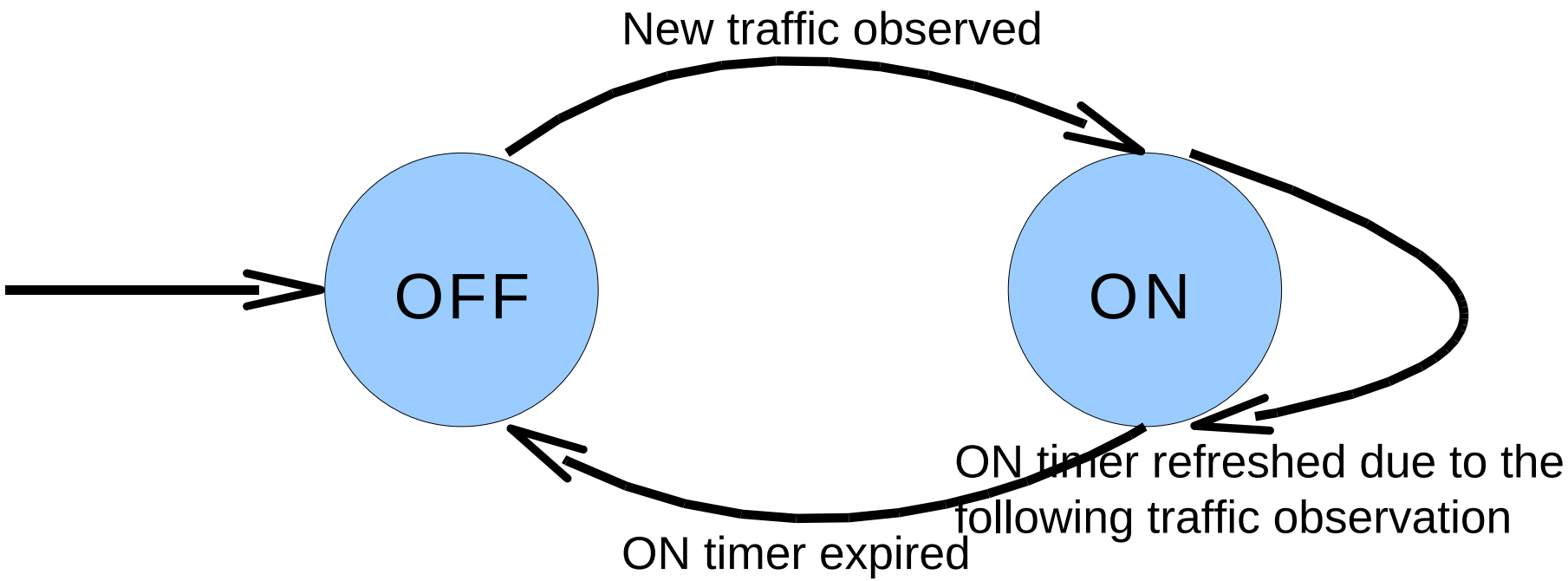
Traffic scenario categorization for WSN

- 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

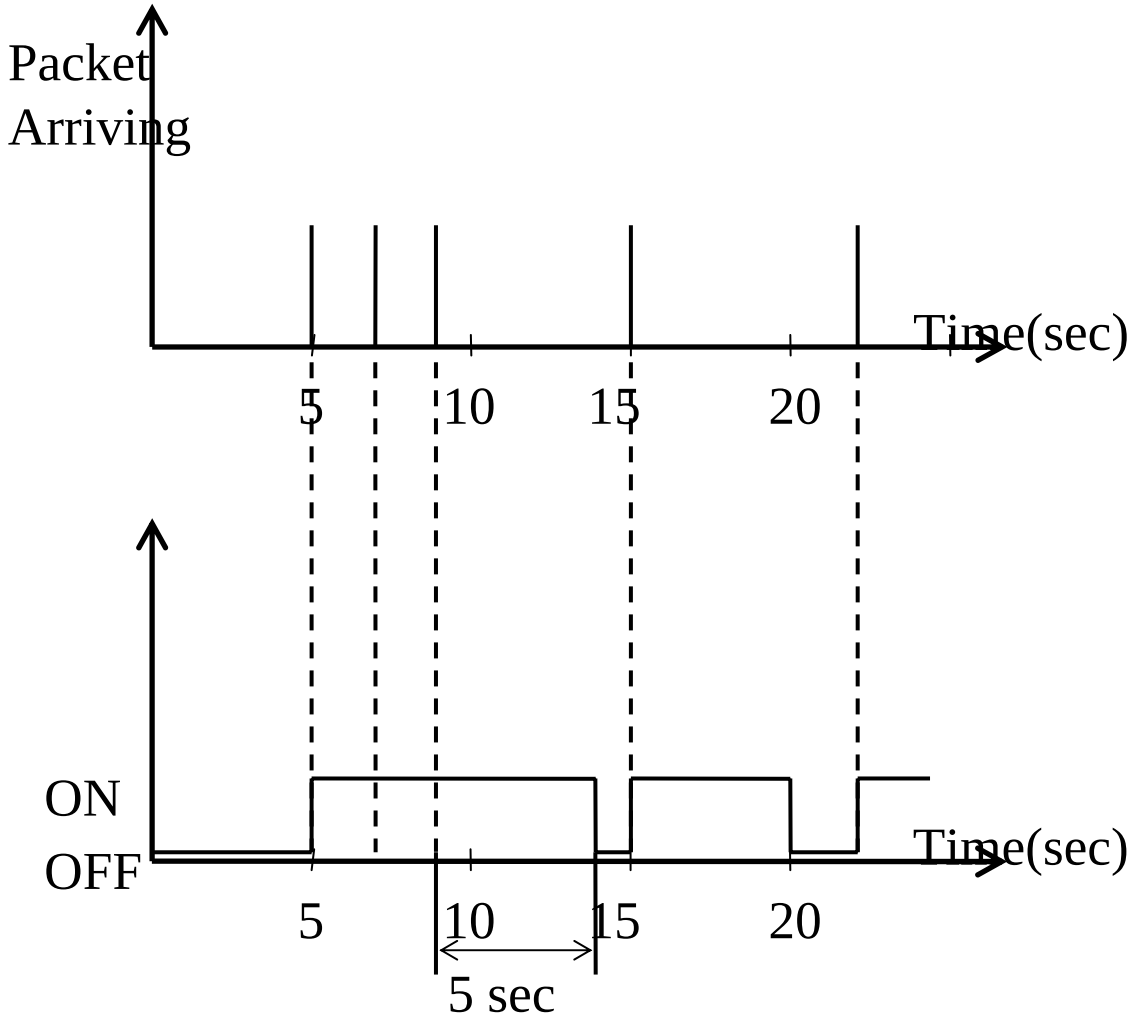
Traffic modeling for WSN

- 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

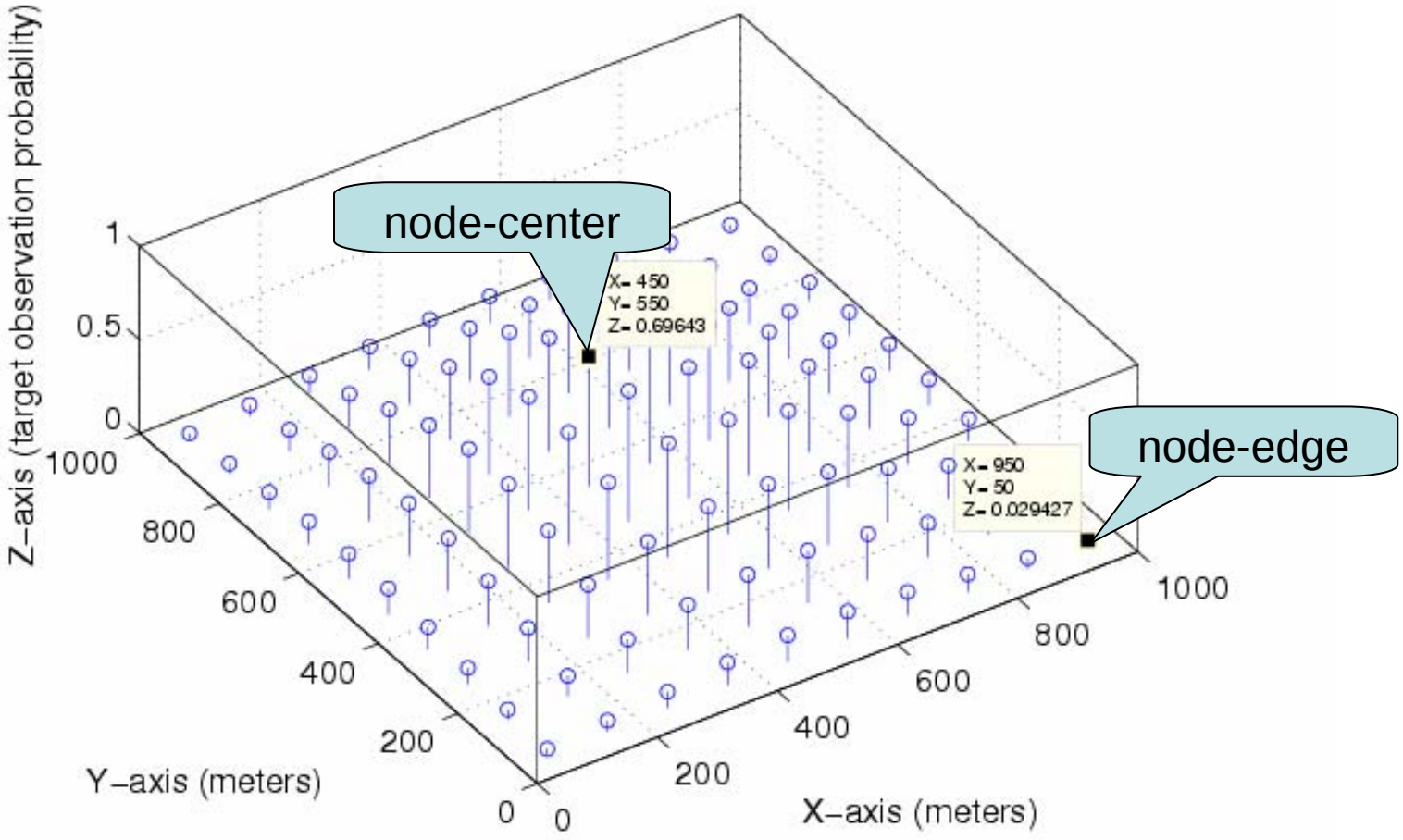
- Methods:
  - By carrying simulations in a modified ns-2 (http://apachepersonal.miun.se/~qinwan/resources.htm)
  - Capturing traffic bursts using ON/OFF model
  - Fitting ON/OFF period distributions to get insights

Traffic modeling – WSN for target tracking

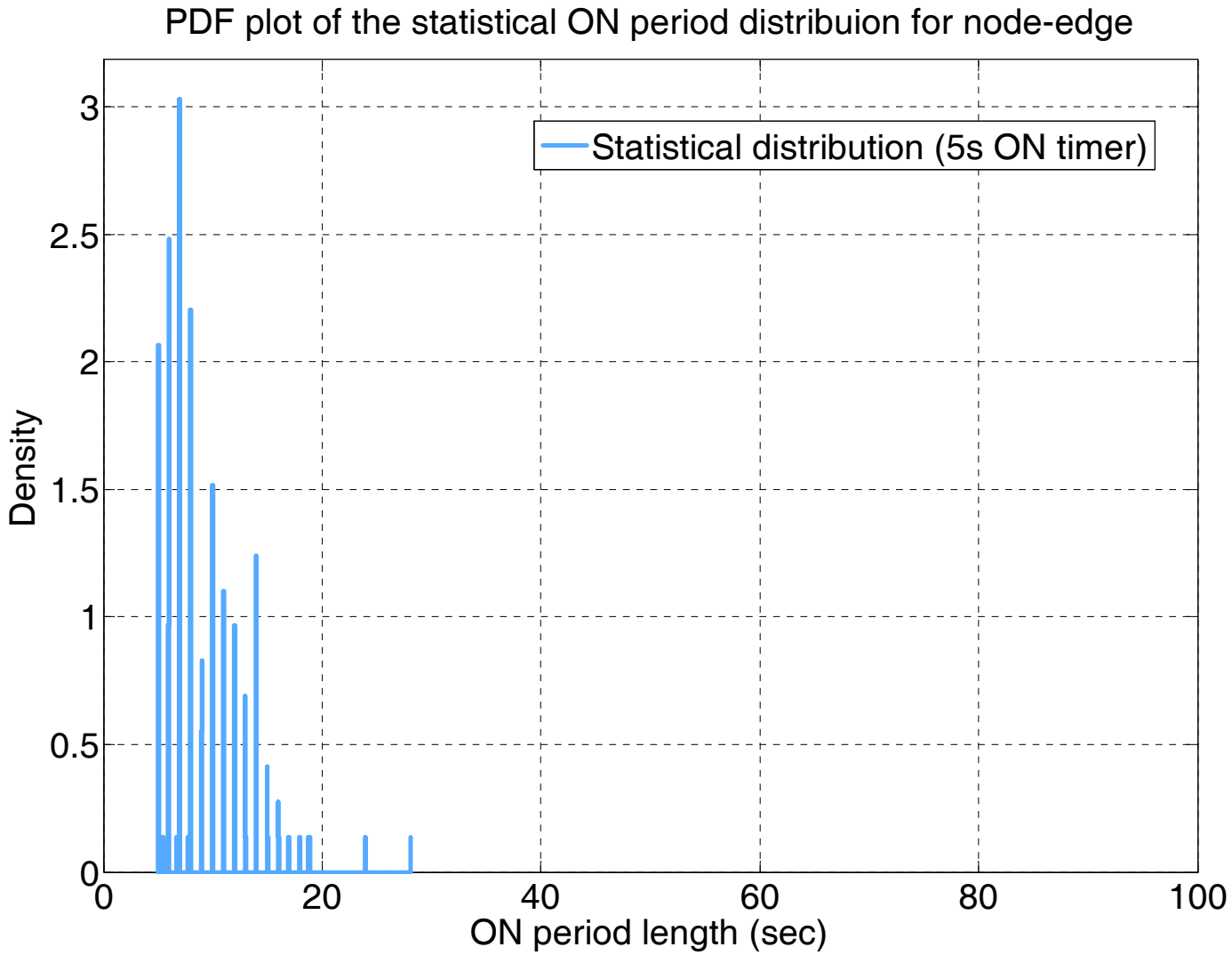
- Simulation settings:
  - Nodes number: 100
  - Deployment area: 1000m×1000m
  - One sink: located in the center
  - One target: randomly moving around
  - Sensing range: ~250m
  - Communication range: ~250m
  - Routing: multi-hop AODV protocol

Traffic modeling – WSN for target tracking

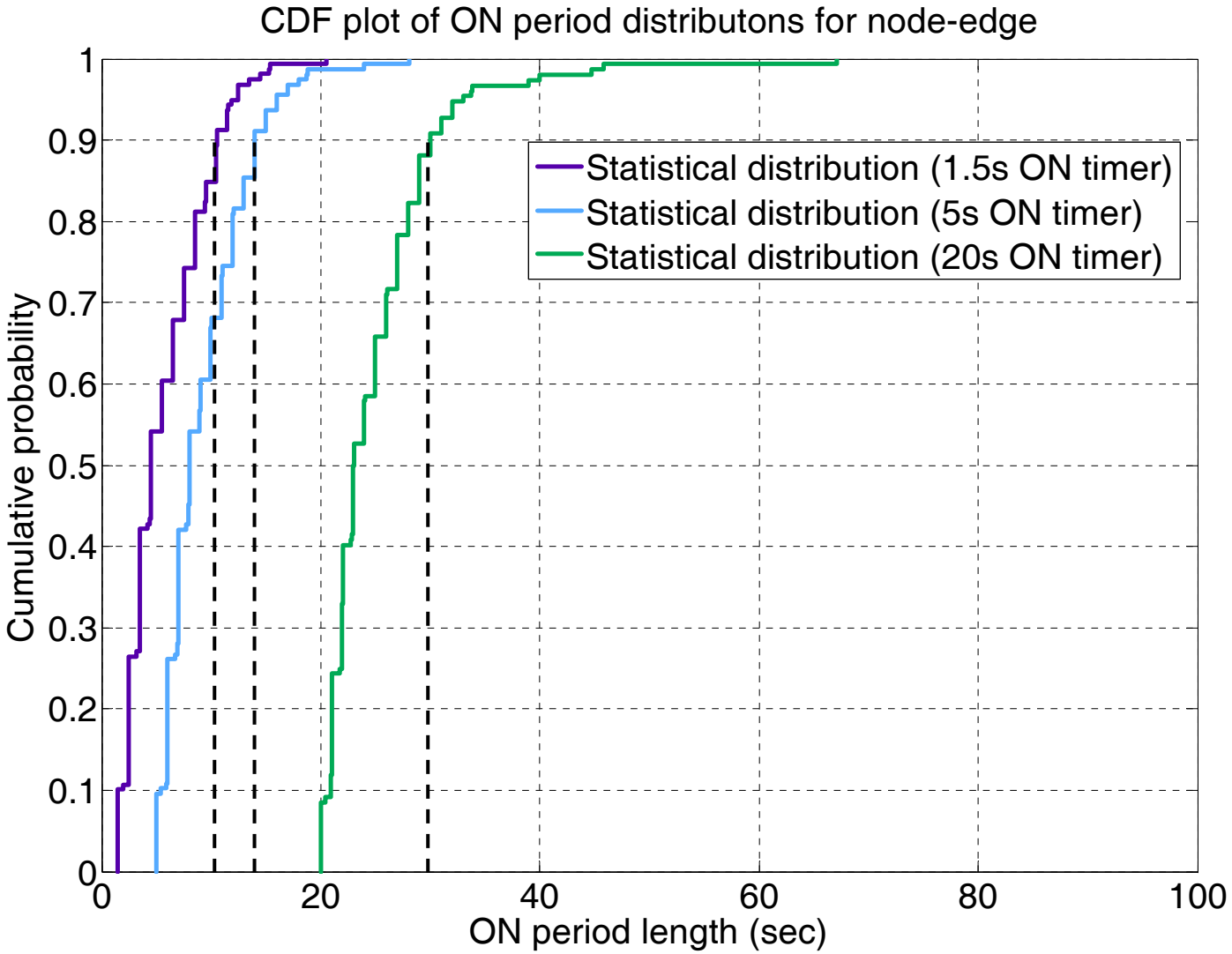
Distribution of target observation probability:



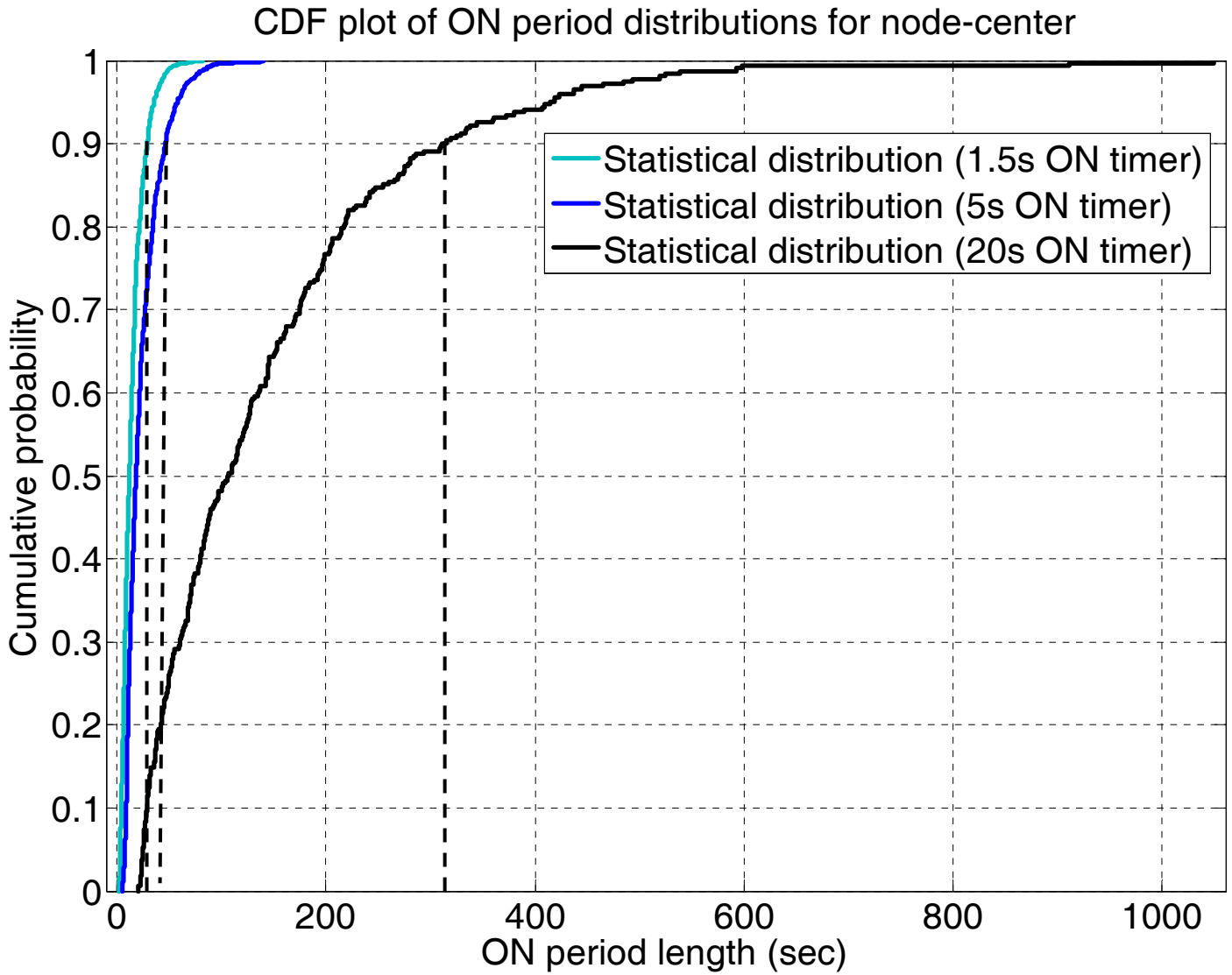
Results – ON period distribution



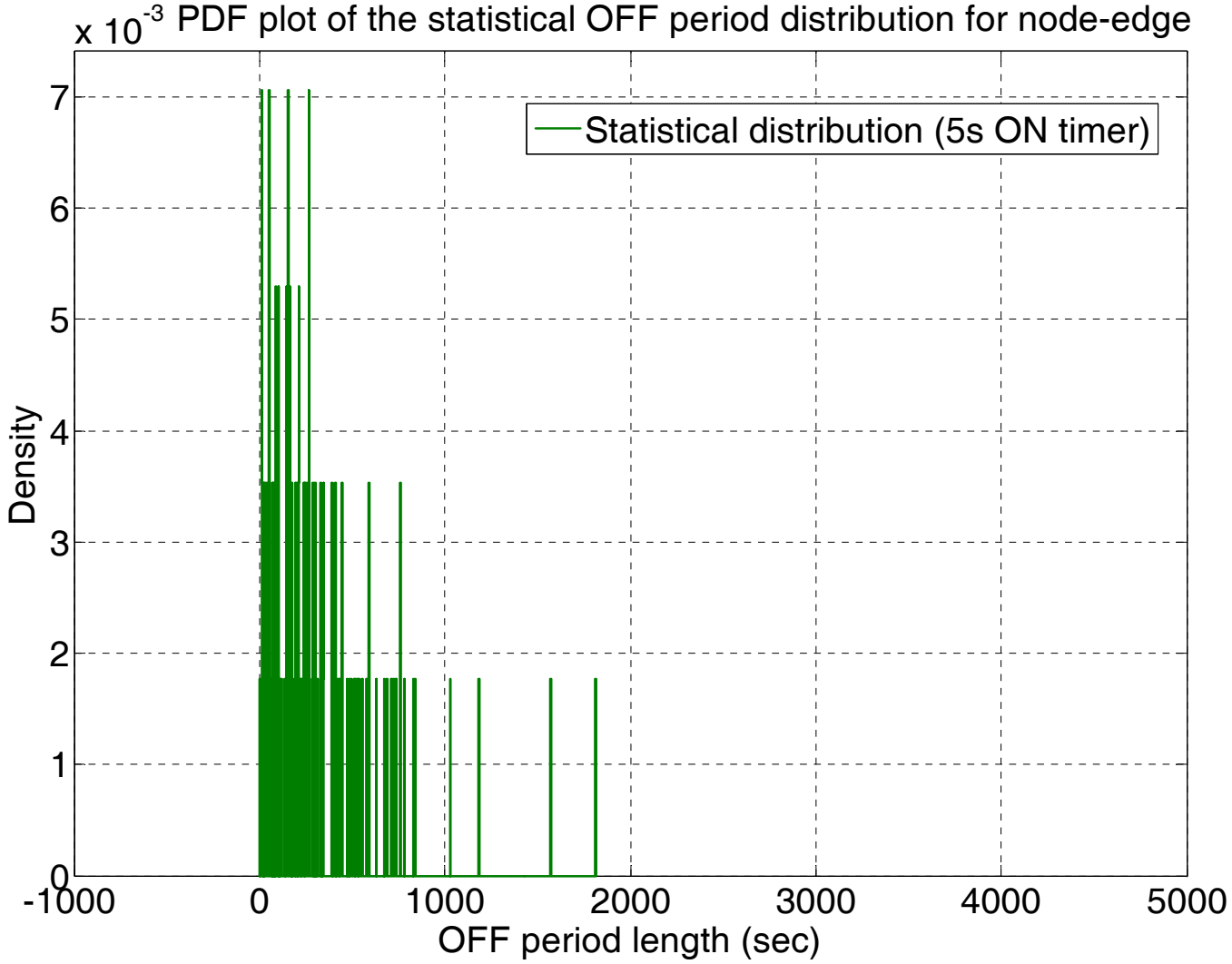
Results – ON period distribution



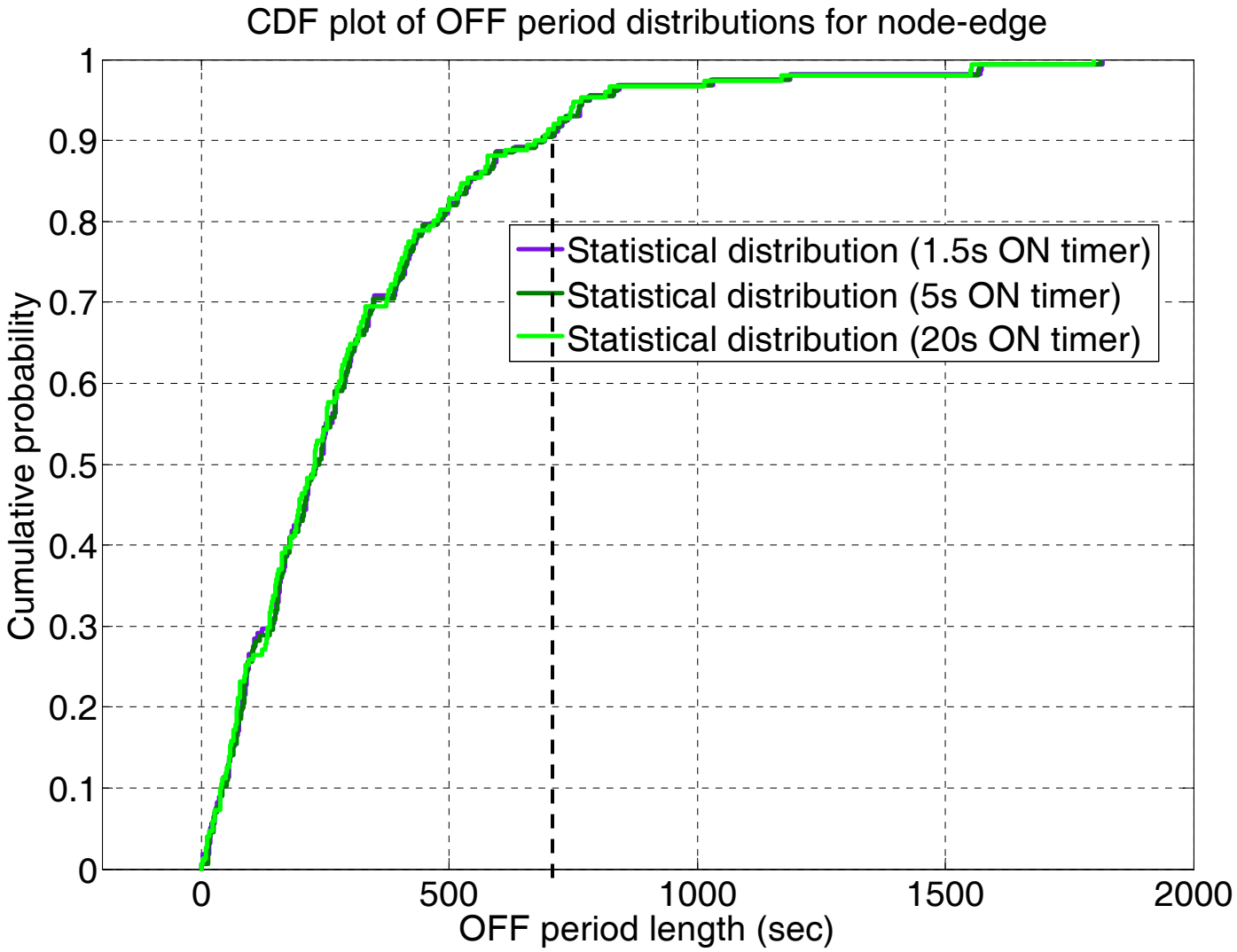
Results – ON period distribution



Results – OFF period distribution



Results – OFF period distribution



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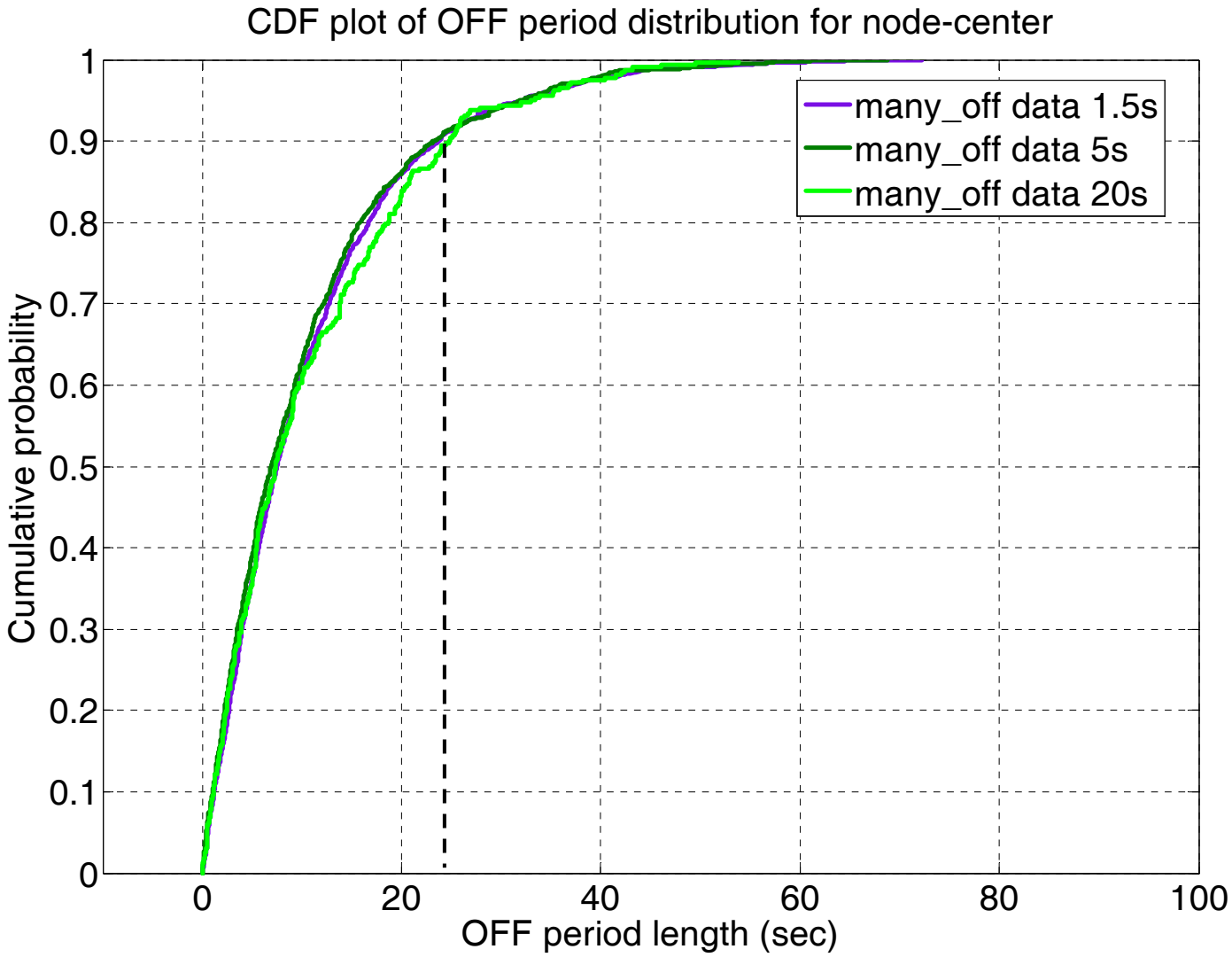


ON/OFF period distribution fitting

- Generalized Pareto distribution
  - Probability density function:

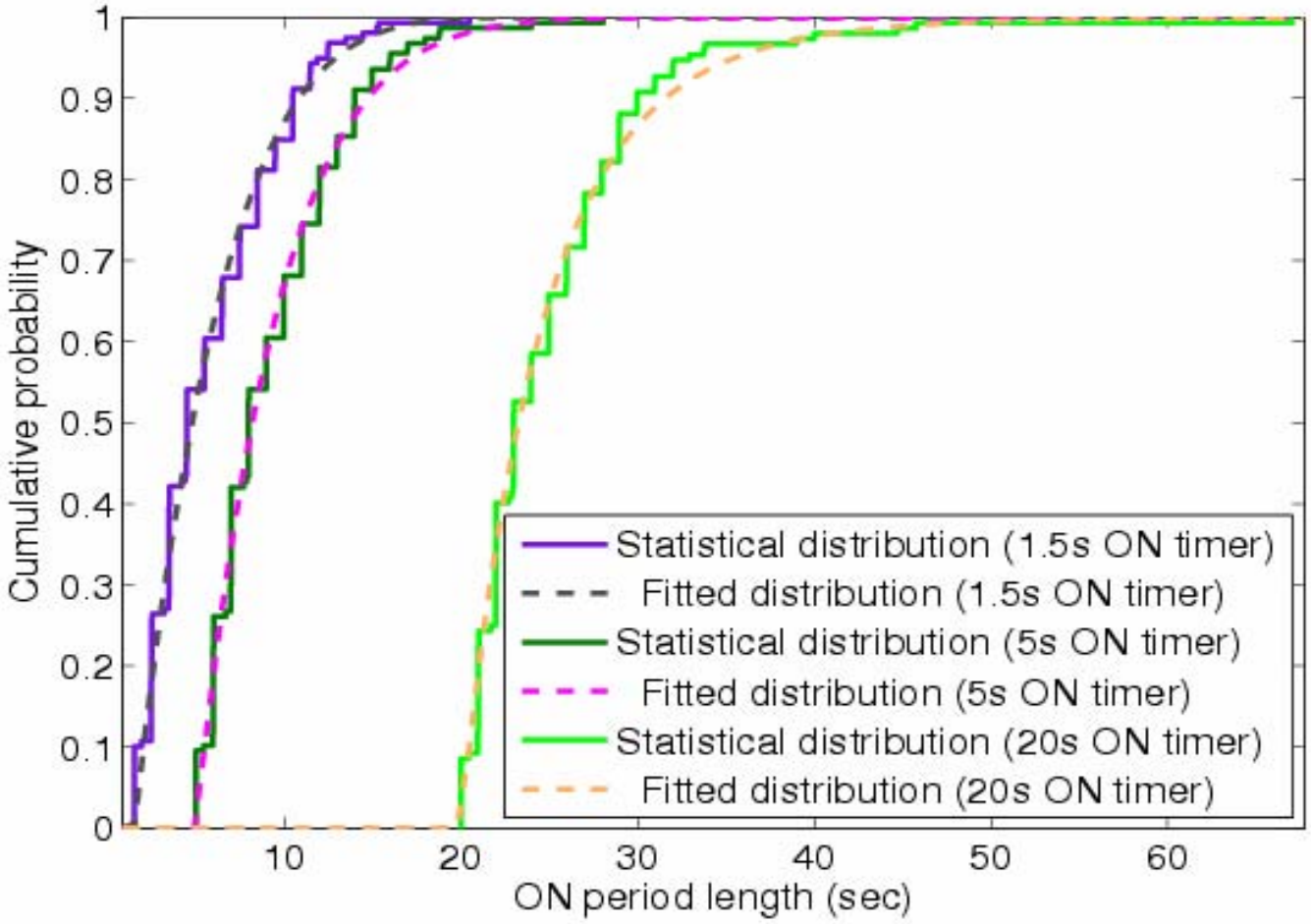
$$y = f(x \mid k, \sigma, \theta) = \left(\frac{1}{\sigma}\right)\left(1 + k\frac{(x-\theta)}{\sigma}\right)^{-1-\frac{1}{k}}, \qquad \theta < x$$

  - Useful property:

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

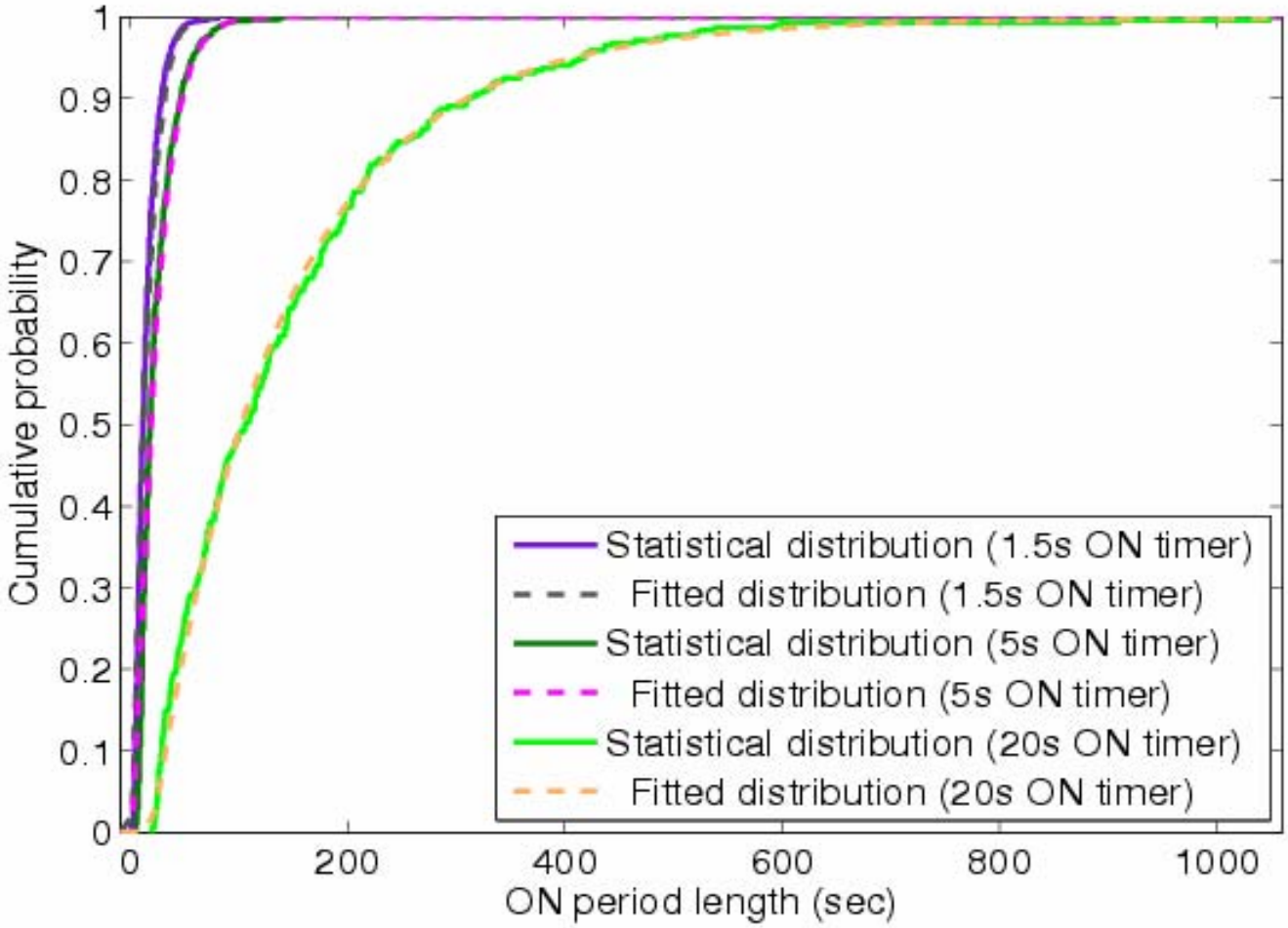
ON/OFF period distribution fitting

Fitted ON period distribution for node-edge



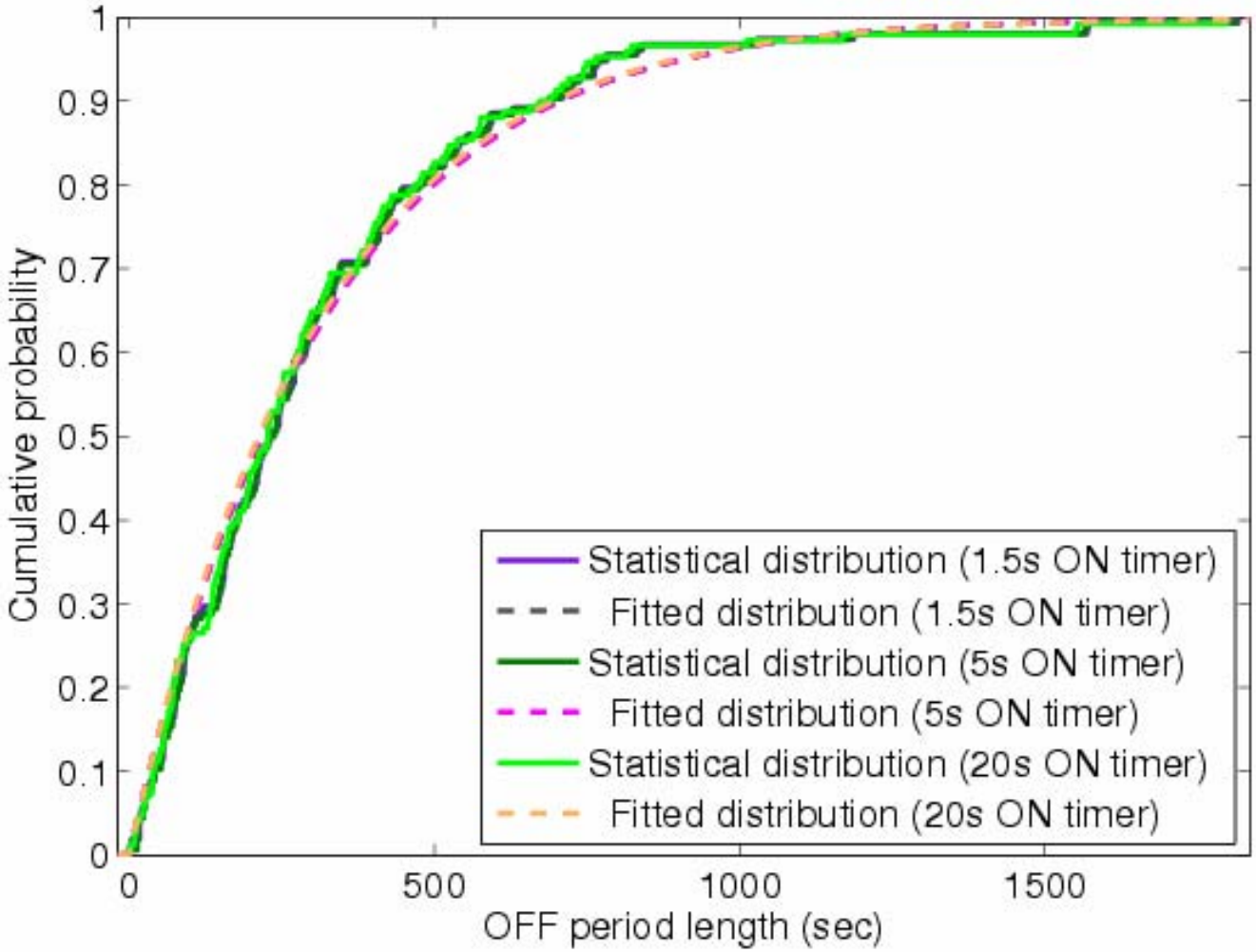
ON/OFF period distribution fitting

Fitted ON period distribution for node-center



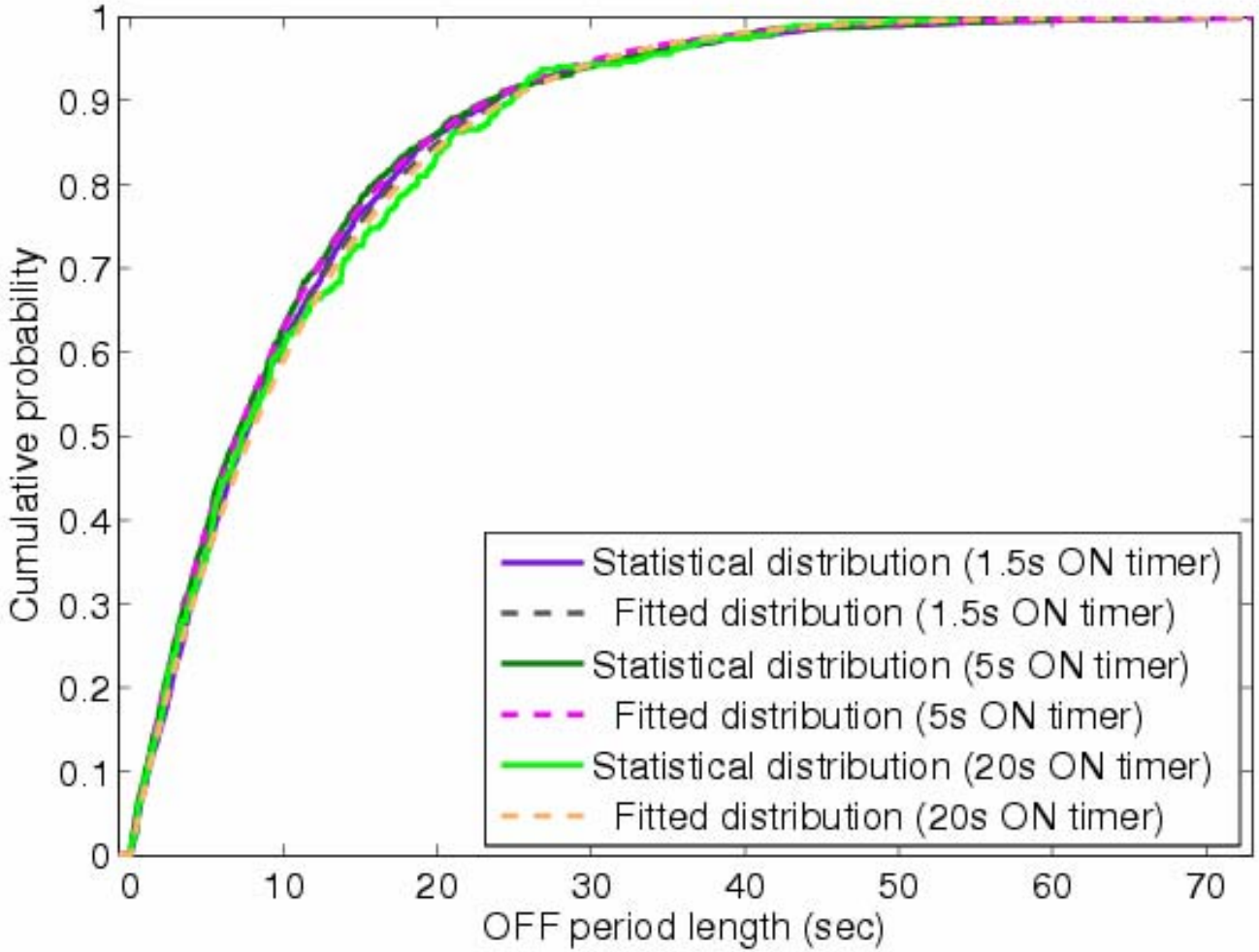
ON/OFF period distribution fitting

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	*node-edge*			*node-center*			*node-edge*			*node-center*		
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	1.80	19.65	115	317.1	317.9	308.9	10	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
$x \mid F(\mid Period \mid \leq x) = 0.99$ (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

$\frac{x}{Mean} < 5$

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 insensible 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!