

BoboCEP: a Fault-Tolerant Complex Event Processing Engine for Edge Computing in Internet of Things

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Summary

Internet of Things (IoT) systems rely on a multitude of heterogeneous hardware, software, services, and standards to represent Internet-connected *Things* and their environments. However, despite this heterogeneity, emerging standardisation efforts ([Kaeabisch et al., 2020](#)) have recognised three core affordances applicable to all Things, namely: (1) *properties*, the internal states of a Thing; (2) *events*, significant state changes within a Thing; and (3) *actions*, invocations of state changes onto a Thing.

BoboCEP is a *Complex Event Processing* (CEP) engine designed for edge computing in IoT systems that is able to provide a reliable platform on which to implement all three essential Thing affordances. This makes it a unified, dependable platform on which to base IoT system development that is privacy-focussed by keeping data flow and processing at the network edge. For example, a developer considers what *phenomena* they would like BoboCEP to be able to detect, and denotes one or more *patterns* that must emerge in the data stream that, if fulfilled by the relevant data, would infer the existence of a given phenomenon. On pattern fulfilment, an action may be executed. The data stream represents properties from various Things, the fulfillment of a pattern represents event detection, and the action affordance is applicable on event detection.

Statement of Need

BoboCEP has existed for several years as a CEP engine to provide inferential reasoning and decision-making on streaming data ([Power & Kotonya, 2020](#)) and has continually been developed ever since to become a robust platform on which to deploy IoT systems. It adopts an *information flow processing* (IFP) architecture that consumes a data stream from diverse sources (i.e., Things) ([Cugola & Margara, 2012](#)). These data enter the system in a serialised and uncorrelated manner (i.e., *simple* events), which are then compared against user-designed *patterns* that seek to recognise temporal relationships. If data satisfies its conditions, then a *complex* event is generated and an action may be executed consequently.

Unlike other CEP systems, which focus on cloud-based big data platforms ([Giatrakos et al., 2020](#)), BoboCEP is designed for dependable edge computing in IoT systems by extending the IFP architecture to additionally provide *fault tolerance* (FT) via the active replication of partially-completed complex events across multiple instances of the software. That is, it can be deployed on n devices across the network edge and is able to protect the system against, at most, $n - 1$ software failures. This is crucial to ensure that valuable insights into patterns emerging across the ever-changing cyber-physical environment are not missed, leading to events not being recognised and necessary actions not triggering.

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