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# Analytical decisional model for latency aware publish/subscribe systems on MANET

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This paper proposes an analytical model for latency aware publish/subscribe systems on mobile ad hoc networks. The proposed approach combines both proactive and reactive statistical analysis. On the one hand, the reactive analysis, suitable for multimedia applications, detects failures by approximating latency series with the Gumbel distribution. On the other hand, the proactive analysis, suitable for crisis management applications, forecasts failures occurrence relying on Auto Regression or Auto Regressive Integrated Moving Average Formulas. Finally, a hybrid analysis was proposed by dynamically switching from reactive to predictive forms of analysis whenever quality of service violations are noticed. In order to extract failure cause, we refer to the correlation method once failure was detected or predicted. Simulations done under different scenarios proved the efficiency and accuracy of the proposed scheme.



## 1. Introduction

Mobile ad hoc networks (MANET) (Basagni et al., 2004; Zhang et al., 2006) are a set of nodes, communicating meaning wireless channel without any centralized control. Each node may be either a data sender, a data receiver or an intermediate router. The main characteristic of MANET is the frequent mobility of its nodes leading to some dynamic changes of topology. Nodes mobility in such networks introduces possible disconnections between adjacent nodes, and more generally quality of service (QoS) degradation issues (such as long delay, low throughput) that do not fit well with QoS requirements of QoS sensitive applications such as multimedia (audio, video) applications.

At the routing (i.e. third layer in the OSI Network) layer, different QoS oriented routing protocols have been introduced aiming at finding the corresponding path between the source and the destination. Routing protocols (Mammeri, 2010; Yanjing Sun and Hu, 2014; Sridhara et al., 2013; Bara et al., 2013; Chena et al., 2010) have to be able to deal with crash and breakage affecting link and re-route messages, whenever any faults affecting the intermediate nodes on the route due (for instance) to mobility is susceptible to make inadequate the end-to-end route. However, if there is no such a path between end-nodes, the targeted QoS cannot be provided. More generally, maintaining a QoS level that matches the application level QoS requirements is a very complex task.

Hence, it becomes very necessary for various applications to have a strength QoS mechanism support especially those requiring a special need for QoS like crisis management applications. Thus, above the routing layer, these applications introduced the middleware layer in order to solve problems unmanageable by the previous one.

At the middleware layer, some communication paradigms have been evaluated in order to find a way to connect mobile entities in the mobile network such us publish/subscribe, remote procedure calls, and tuple spaces paradigms (Collins and Bagrodia, 2012; Denkoa et al., 2009).

Publish/subscribe has been well evaluated in a qualitative comparison between these communication patterns.

In this paper, we aim to provide a QoS management at the middleware layer while assuming a best effort flux at the routing layer. We also use of the publish/subscribe paradigm to communicate mobile entities in MANET.

A publish/subscribe (pub/sub) (Carzaniga et al., 2001) communicating system is a decoupled interaction between publishers (or producers) and receivers (or consumers). Publishers provide messages to

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be delivered to consumers whose previously subscribe for that event. This is ensured by an intermediate component named broker (or dispatcher or channel manager). The broker is the most important component of a pub/sub communication infrastructure. Two of its main functions are: (1) to perform the matching between the incoming events and the subscriptions previously registered, and (2) to send incoming events to the receivers that have expressed an interest in the events. Let us note that a pub/sub communication system may include several brokers between final senders and receivers.

Applied at the middleware level (i.e. between the Application and the Transport layers of the OSI reference model), the pub/sub paradigm is promising for MANET thanks to its decoupling nature.

Several research efforts have been already accomplished in the study of pub/sub paradigm to enhance QoS in MANET and to tolerate failures (Cugola and Picco, 2006; Denkoa et al., 2009; Kazemzadeh and Jacobsen, 2009; Malekpour et al., 2011; Esposito et al., 2012; 2013; Maye et al., 2012; Zhao and Wu, 2013; Esposito et al., 2014; Hoffert et al., 2009). In this direction, adopting autonomic and self-reconfiguring system have gained raising interest during last years. Indeed, the challenge is that the system have to be ready to recover failures beyond human intervention. Autonomic systems are structured following the IBM autonomic process (Jacob et al., 0000) into four steps namely monitoring, analysis, plan and execution. Significant efforts have been dedicated in each of these phase.

Indeed, in the execution step, faults recovery schemes have been proposed in order to restore system functioning (Kim et al., 2010; Chen and Schwan, 2005; Avvenuti et al., 2005; Cugola and Picco, 2006; Denko et al., 2007; Pankajakshan and Rao, 2012). The starting point of these approaches relies basically on the hypothesis that QoS maintenance might be improved thanks to a dynamic location of the brokers on the nodes. Our starting point is similar and considers that the broker location may be driven by two main criteria: the mobility of the hosting nodes, and the QoS (here the latency) observed between nodes hosting adjacent brokers along the data path. When mobility increases, we assume that there is a serious risk of QoS degradation between the broker and its neighbor brokers, and that the broker location has to be reconsidered. Similarly, when the observed latency between two adjacent brokers increases, we assume that this involves a problem (e.g. node congestion) that is time to reconsider the broker location.

As a solution to the mentioned faults problem, reconfiguration actions be elaborated in order to safeguard system survivability according to each QoS degradation cause. In fact, adaptation can be achieved through moving a nonstable broker to another location (i.e node) in the field providing a better QoS level whenever failure is due to a node mobility. It is also possible to split an overloaded broker into equilibrate brokers load (Abid et al., 2013).

In our study, the general approach is supposed to be performed following the autonomic paradigm. Our contribution lies in the monitoring and analysis steps of the MAPE loop. Monitoring consists in computing latency values taken by events between neighboring brokers. The analysis consists first in predicting/detecting QoS degradation and then in looking for the cause of the degradation which we would call the diagnosis.

The previously cited contributions that target the same issues are based on the comparison of QoS parameters values with fixed thresholds and are restricted to a specific subscription language and a specific topology. Otherwise, the approaches proposed in the literature impose a specific form of analysis (i.e. either reactive of predictive), which cannot be suitable for all types of applications. Our approach is different in the way we propose to base the analysis on the dynamic thresholds enabling us to take into account network dynamicity. The analysis step is driven thanks to an analytical model combining reactive, predictive and hybrid analysis which allows meeting the different kinds of application requirements.

The new model provides then three types of analysis. The developer must then choose the form of analysis considering his application: (1) a reactive analysis (Lahyani et al., 2012c) which is best adapted to multimedia applications where users need to have a reliable video transmissions. (2) A proactive analysis (Lahyani et al., 2012d; 2012b) which fits the best to critical applications such as crisis management. A failure in such applications must be predicted since it may lead to a catastrophe. (3) Hybrid analysis (Lahyani et al., 2012) which is a mixture of the reactive and the predictive forms of analysis. The new analytical module is more generated since it is not specific to a particular application. It may be applied to different types of problems (multimedia, crisis management applications…).

Our customizable approach relies on mathematical models. Indeed, the reactive analysis which is more suitable for video streaming multimedia applications, approximates the monitored latency values with the Gumbel (Giorgi and Narduzzi, 2008) distribution towards computing thresholds. Latency is then compared with adjustable thresholds updated using the Exponential Weighted Moving Average Formula.

Proactive analysis is better appropriate to crisis management applications where failures should be omitted since it leads to catastrophe. The predictive approach forecasts failures by adopting the Auto Regression (Knight, 1989) as well as the Auto Regressive Integrated Moving Average Method (Ruey and Tsay, 2008). However, the hybrid analysis is a combination between the two pre-described forms of analysis. Once QoS degradation is noticed, diagnosis step involved in the analysis module is carried out using the correlation method[1] in order to identify failure causes. This is very important since adaptation is carried out considering failures causes. Indeed, the proposed decisional module creates opportunities to repair the system.

In order to evaluate the proposed analysis models, simulation was achieved on an ad hoc network using the Jist/Swans Simulator (Barr, 2005). In this paper, new experimental tests were achieved considering different mobility conditions regarding the pause time parameter related to the mobility model. Thus, we realize experiments in medium, low and high mobility scenarios. The Results prove that the proposed analytical framework can efficiently detect/predict failures and save system breakdowns.

Besides, this paper show the benefits gained by introducing the proposed approach in the considered publish/subscribe system when compared with other scenarios integrating analysis module relying on fixed thresholds.

The remainder of this paper was organized as follows. The second section introduced the related work to the topic. A detailed description of the proposed decisional model for latency aware pub/sub systems on MANET was detailed in Section 3. Thereafter, in Sections 4 and 5, some evaluations using simulation experiments were described. Finally, we drew our conclusions before suggesting some perspectives in Section 6.

## 2. State of the art

Significant research study has been devoted to the provision of QoS guarantees in MANETs at the routing layer (the third layer in the OSI model). Considering some QoS parameters, efficient routing protocols in MANET aim to find available paths for a connection based on QoS requirements applications (Sridhara et al., 2013; Bara et al., 2013; Chena et al., 2010). To support such QoS requirements, some QoS parameters have been incorporated in route finding and maintenance often given in terms of bandwidth, delay, loss rate, energy, throughput and reliability constraint.

Unlike previous works on the QoS supervision, our paper contributes to the existing literature at the middleware level. At this

[1] http://www.stat.wmich.edu/s216/book/node122.html.