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Influence of Network Speed on Structured Query Language (SQL) Database Data Transmission Performance in an Internet of Things (IoT) Sensing Device on Single Board Computers (SBC)

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Abstract. One of the crucial elements in an Internet of Things (IoT) environment is a database. IoT performance will be at stake if the wrong database is adopted. In this research, three Structured Query Language (SQL) databases were tested against multiple network speeds in an IoT device. Single board computers (SBC) were used as a media of testing instead of an ordinary computer. A controlled wireless sensor network (WSN) was developed with several uniform constants and variable network speeds. A new data transmission rate equation also was proposed and tested. From the result, it was found that not all SQL databases can cater IoT devices. Some of them showed that performance decreased along with network speed. The correlation, between 0.90 and 0.96, proved the strong influence between the research subjects. In addition, file-type database is the best option available for SQL-wise IoT storage.

1.   **Introduction**

An emerging advancement in the Internet of Things (IoT) has the attention of the world and is quickly launching it into the 4th Industrial Revolution. Terms like 'data farming' and 'sensor networks' have become a frequent subject of discussion. Data transmission from sensors such as GPS, thermometers, or vital signs monitors need a robust communication network. Different applications and sensor types have different requirements for the transmission of data, but all must consider loss-tolerance, timeliness, priority and completeness.

The aim of this paper is to analyze the relationship between network speed and data transmission rates through wireless sensor networks (WSN). WSN are a distributed group of sensors able to secure data at a low cost that can be used for real-time monitoring of physical changes in multiple environments. This paper will focus on data transmission rates of different SQL databases by analyzing the latency of data between these WSN sensor nodes to the databases. Meanwhile, these selected SQL databases will be embedded in single board computers (SBC) which are quick becoming good mediums between sensors and farming servers.

1.1. SQL Databases

In recent development, alternative database systems called NoSQL databases have been introduced to overcome the problems of SQL databases. However, the non-relational concept in NoSQL databases make it hard to do reporting. So, even though the development of NoSQL databases is rapidly evolving, they cannot contend with the vast and easy adoption of SQL-based storage. In this paper, three known SQL databases will be tested on their latency in assisting fast data transmission in an IoT environment. With our simulation in mind, these databases must be able to be embedded in single board computers, which is the main factor for the implementation of IoT with an open-source license. The databases are:

(a)   SQLite: a file-based database. It is extremely portable and reliable because it consists of a single file on the disk. It has an amazing library that gets implanted inside the application that uses its interface.

(b)   MySQL: a full-featured open source relational database management system (RDBMS). The data stored are grouped using SQL to access data.

(c)   PostgreSQL: a standard-compliant and extensible database. It is a high-performance, object-oriented and relational database. The support for concurrency is achieved with varied locking modes.

These relational databases are among the most famous data storage systems for an IoT environment. All databases should support the fast pace of data transmission, However, the implementation of them in single board computers is questionable; is the data transmission performance influenced by network speed or not?

1.2. Single Board Computers (SBC)

SBC are computers with small form factor. It is widely used in education, especially in microcontroller learning or programming. The need for small form factor processing devices in the IoT environment has contributed to its widespread adoption. Starting with SolidRun in early 1996 to the latest Wandboard in Spring 2018, the processors have become faster and device memory bigger. In IoT environments, these SBC can replace standard computers, being low cost and easily placed in remote areas. Several successful research papers have confirmed SBC capabilities, as reported by Stylia for DDoS attack [1], Mansoor in smart cities [2], and Guha Roy in message telemetry [3]. In this paper, we will use Raspberry Pi 3 B+ SBC as a server while Lolin NodeMCU as a client to perform the data transmission analysis in the SBC.

1.3. Related Works

Several researchers have done their work on comparing storage databases. In [4], SQL and NoSQL databases are compared. Experiments focused on concepts and characters of the databases instead of hardware. The comparison was made by determining the performance of the different databases. They found out that SQL databases are more stable in response, but NoSQL provided faster query response. Furthermore, [5] presented a discussion between the use of "without database approach" (WDA) and the SQL databases. Based on their result, the use of WDA gave a better performance result. Through this paper, we found that latency of data transmission was not well discussed as they focused more on data queuing. It is a loophole in a data transmission analysis, since data transmission performance in IoT have many parameters. Finally, as discussed in [6], there are three major metrics for evaluating data transmission performance in sensor devices: network delay, average CPU, and memory usage. In our paper, only network delay will be experimented by employing different limitations on network speed

2**.**   **Methodology**

2.1   Hardware Preparation

Three Raspberry Pi 3 B+ and Lolin NodeMCU were chosen as the main SBC components of this research, whereas a DLink Wireless Router DIR-868L was employed as the WSN controller. For each SBC, different databases were embedded in its built-in storage. However, due to vast data, we moved these databases into separate USB drives. Figure 1 shows the WSN architecture and the embedded databases. Each node consisted of three sensors, one each for humidity/temperature, light, and carbon monoxide. These nodes sent the data from the sensors to the SBC through the router. This architecture follows the data integration in relational databases [7]. The hardware setup is shown in Figure 2.

Figure 1. WSN architecture Mapping

Figure 2. Hardware setup
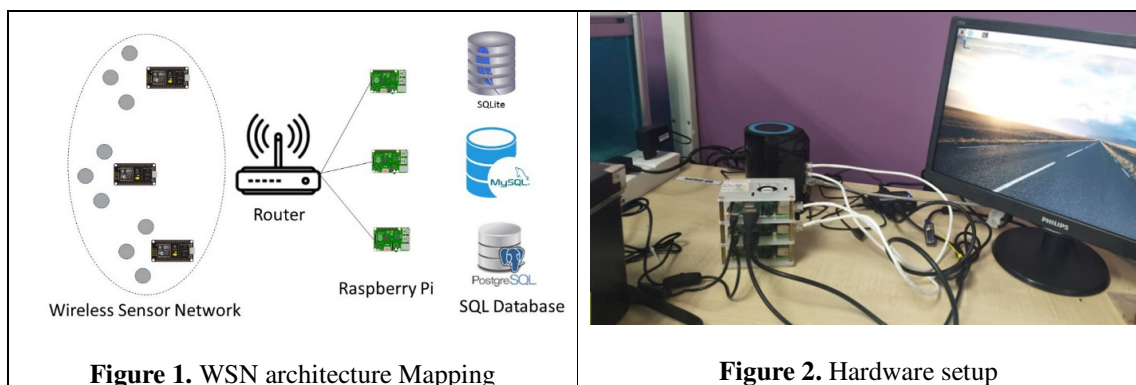
2.2   Software Preparation

To enable the WSN, Dynamic Host Configuration Protocol (DHCP) was set up. The sensor nodes were the client, while the SBC was the server. A router was connected to the laboratory network point to obtain real-time data from the Network Time Protocol (NTP) server. The nodes sensed change in the environment, captured the data and sent it to the respective SBCs with different databases. The time in milliseconds was taken when the packet of data was sent, and taken again when the packet of data arrived. This setting was constant for the three data capturing services. This semantic query concept is inspired by the query expansion technique [8]. Figure 3 explains how the data was sent back and forth within the simulation framework.
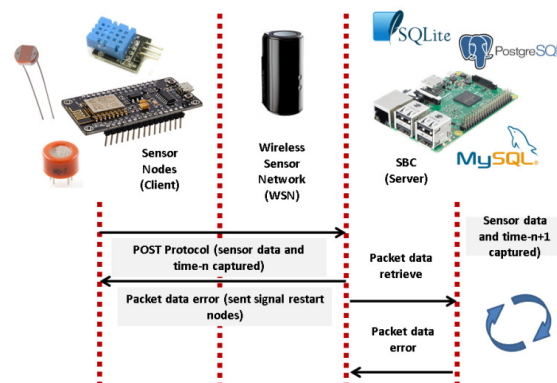

Figure 3. WSN with Hyper Text Transfer Protocol (HTTP) Architecture

2.3   Data Transmission Performance Rates Metrics

The WSN performance for sending and retrieving data can be measured by data latency. Isakovic had defined this term as a time delay between two machines when sending and receiving a packet of data [9]. In this paper, the equation for data latency is defined as

$$D_L = t_{(n+1)} - t_{(n)} \tag{1}$$

where D_L = data latency in millisecond, t = timestamp, n = data in nodes and $n + 1$ = data in database

In this experiment, to determine the performance, packet data delay transmission was considered. Data stream classification [10] had been used to reduce the hardware load.

$$D_T = N / R \tag{2}$$

where D_T = transmission delay in millisecond, N = number of bits and R = bits per millisecond.

Therefore, the data transmission performance rates can be determined as

$$D_{TR} = D_L / D_T \tag{3}$$

where D_{TR} = data transmission performance rates.

Based on these equations, it is understood that the higher data transmission rates, the better the SQL database performed in the SBC.

3.   Result and Discussion

The data transmission performance was observed using three different network speeds: 10bps, 100bps, and 1000bps. These speeds were throttled down using a network management program embedded in the router. The summary of results comparing the three significant network speeds is shown in Table 1. This IoT system was executed for 240 hours with a delay between readings being about five seconds (540 readings per database). For each data transmission, the latency rates were calculated using Formula 1 to 3 in real time. Then, the average of rate of data latency was calculated. We plotted the graph to visualise the relationship between network speed and data transmission performance in Figure 4.

Table 1. Summary of result for the data transmission performance of different SQL databases across three significant network speeds

Network Speed	10 bps			100 bps			1000 bps			Average
Metrics	D_L	D_T	D_{TR}	D_L	D_T	D_{TR}	D_L	D_T	D_{TR}	
SQLite	2.23		0.464	3.35		6.979	4.25		88.542	31.995
MySQL	5.65	4.8	1.177	2.75	0.48	5.729	2.50	0.048	52.083	19.663
PostgreSQL	2.98		0.620	2.78		5.791	3.00		62.500	229.70

In Figure 4(a), the plotted graph shows four further network speeds that was implemented: 200bps, 400bps, 600bps and 800bps. The inclusion of these network speeds was to clearer see the relationship between network speed and data transmission performance. The correlation between these two attributes are presented in Figure 4(b). All three databases had strong speed-transmission performance relationships, with PostgreSQL highly reliant on network speed. However, the other databases were also not far behind.

SQLite showed the highest average of data transmission rates in this experiment. However, based on network speed, PostgreSQL showed the best solution for any speed. On the other hand, MySQL database showed higher data transmission performance for small data, good for enterprise-level data storage. Comparing this to [4], [5] and [6], it is proven that SQL databases are reliable for IoT sensing devices embedded in SBC.

(a)   b)
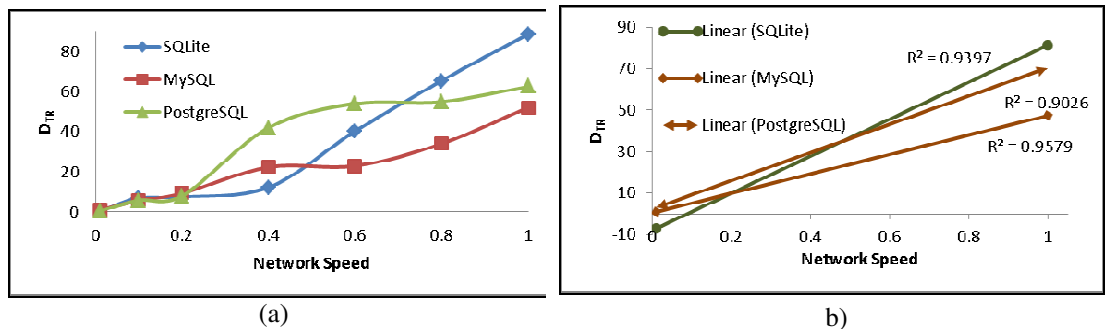
Figure 4. SQL-wise database in SBC data transmission (a) performance rates and
(b) correlation analysis

4.   Conclusion

From this research, we can conclude that not all databases are ready an IoT environment in SBC. Even with the same network infrastructure and hardware, data transmission rates are highly dependable to network speed. However, the best finding is that MySQL seems reliable in any computer architecture. It is robust database which does not rely too much on network architecture. On the other hand, PostgreSQL with its file-based architecture is reliable with higher network speeds; this performance is promising for newly-introduced 5G networks.

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