Development of Information and Communication Technology Infrastructure in School using an Approach of the Network Development Life Cycle Method

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Abstract. Information and Communication Technology (ICT) has become an essential requirement for the wider community, including in the educational environment. ICT has a vital role in supporting activities ranging from planning, operations, supervision, analysis to evaluation. In recent years, ICT has been considered mandatory for its existence in the educational environment. ICT can simplify the activities of teaching and learning process (TLP). ICT also closes distances apart and maintains the quality of TLP standards. This paper will describe the results of ICT development in a school using the approach method of network development life cycle. The result is that the connection to one Internet service provider being split into two networks, i.e. wired and wireless local area network. The selected bandwidth management methods are both simple queue and per connection queue. Besides, the terrace area on the 1st and 2nd floor can be served with very good to excellent quality. Whereas the terrace area on the 3rd floor can only catch low-quality signals without Internet connection. Moreover, applying the same service set identifier and password to both wireless routers allows users to handover between two wireless networks without having to re-register and reconnect to the serving network.

Keyword: information and communication technology (ICT); network development life cycle; bandwidth management; wireless local area network

1. Introduction

Information and Communication Technology (ICT) has become an essential requirement for the community. In the educational environment, ICT plays a vital role in supporting activities such as planning, operations, supervision, analysis and evaluation. At present, ICT facilities can be considered mandatory for their existence in the educational environment. In addition to facilitating the Teaching and Learning Process (TLP) activities, ICTs also close separate distances and maintain the quality of TLP standards. The implementation of the Computer-Based National Examination (UNBK) in schools is an example of a serious effort by the government to maintain the quality of education standards. Sekolah Menengah Pertama Muhammadiyah 4 (SMPM-4) is a private junior high school under the care of the Persyarikatan Muhammadiyah. SMPM-4 is located on Jl. Ken Arok No 9 RT 2 RW 9, Pagentan, Singosari, Malang, Province of East Java, the Republic of Indonesia. This school is about 8.4 km to the north from campus 3 of Universitas Widyagama Malang on Jl. Taman Borobudur Indah, Malang. SMPM-4 has been established as a modern school that implements Information Technology
in providing services to students and guardians of students since 2014. Granting certificates is given directly by the General Chairperson and Chairman of the Basic and Middle level Education (DIKDASMEN), Muhammadiyah Regional Leadership Council of East Java in the opening ceremony of the 4th Olympic AD at the Dome of Universitas Muhammadiyah Malang on Saturday, June 14, 2014 [1].

Although the school has been supported by ICT infrastructure, this school has uneven Internet access. The existing ICT infrastructure is still in the form of two wireless modems which are directly connected to two Telkom Speedy Indihome internet access services with 2 Mbps and 10 Mbps bandwidth. Existing Internet access is still limited to Administrative staff with a bandwidth of 2 Mbps, and is dedicated for Computer Laboratory (Lab.) with a bandwidth of 10 Mbps. Fortunately, the principal’s office (Floor 1) and the teacher's room (Floor 2) can still take advantage of Internet access via wireless local area networks from wireless modems. So, Lab. of Science, classrooms and terrace areas still cannot enjoy Internet access to support their learning activities at all times at school. This condition greatly limits the access of information for teachers when teaching and learning in the classroom, and limit students in finding knowledge references when they only rely on printed books. Limitations in human resources and operational funds make it quite difficult for the school to fix this. Thus, the problem of school’s facilities is the condition of ICT network that need updating and the access distribution is not optimal yet [2], [3].

To fully understand the importance of a well-planned network that supports an information system operates correctly, one must understand how the network planning process related to other information systems planning processes. The top-down model is an appropriate way to see the relationship between the network development process and other related information systems, see Figure 1.

As explained [4], the network development life cycle depends on previous development processes, such as strategic business plans, application development life cycles, and data distribution analysis. If the installed network effectively serves information systems that will meet strategic business objectives, then a top-down approach must be taken towards the whole process of developing information systems, which is the life cycle of network development, see Figure 2.
In which, the network development life cycle consists of [5], [6]:

a. Analysis phase
   At this stage, several analyzes are carried out covering the needs, the existing problems, the desires of the user, and the installed topology or network structure.

b. Design phase
   At this stage, a network topology design will be built. Implementation of the design can be in several forms, such as topology structure design, data access design, and wiring layout design, which will provide a clear picture of the project to be built.

c. Simulation prototyping phase
   At this stage, many network engineers will simulate network design with the help of specialized network tools such as Packet Tracer, BOSON, NETSIM, and GNS3.

d. Implementation phase
   In the implementation phase, the network engineer tries to implement everything that has been planned and designed in advance by considering the availability of support and limitations.

e. Monitoring phase
   In this stage, it needs to ensure that the network can run according to the wishes and objectives of the user as stated in the analysis phase.

f. Management phase
   At this stage, a policy needs to be made to ensure the developed system can run well and last long.

While the network planning methodology generally consists of three stages [7]:

a. Identify network requirements.  
   Network design runs parallelly with the user documenting the project objectives.

b. Characterization of installed networks.  
   Information related to the deployed networks and services is collected and analyzed. The analysis is necessary to compare installed network functions with new project goals. The designer determines whether installed devices, infrastructure, and protocols can be used again and determine the new devices and protocols needed to complete the design.

c. Network topology design and its solutions.  
   A common strategy in network planning is to use a top-down approach. In this approach, network applications and service requirements are identified, and then the network is designed.

The offered solution to the school’s problem regarding the availability of its ICT infrastructure is re-design and re-develop the ICT facilities to support the quality TLP.
In this paper, section 2 will discuss the methods being used to solve the problem. Section 3 will present results and discussion. And finally, section 4 will conclude the overall work.

2. Material and methods

This section will discuss the stages of the ICT infrastructure development, which consist of the analysis of existing conditions, analysis of user needs, evaluation and re-design, implementation, and testing.

2.1. Analysis of existing conditions

At this stage, coordination was conducted with the school, site observations, and data collection on existing conditions. From the survey and coordination with the school, some data were obtained related to the availability of ICT infrastructure (Table 1.), user groups (Table 2.), building dimension (Table 3.) and room layout plan. Whereas, the ICT network topology was still in the standard form. In which, the connection links from Internet service providers (ISPs) were connected to modems and then distributed directly using switches and wireless access points (APs).

| Device   | Location       | Capacity/ Quantity |
|----------|----------------|--------------------|
| Modem    | Computer Lab.  | 10 Mbps            |
| Internet | Administration room | 2 Mbps         |
| Switch   | Computer Lab.  | 16 port; 2 units   |
| Computer | Computer Lab.  | 28 units           |
|          | Administration room | 5 units     |

| User group | M | F | Total |
|------------|---|---|-------|
| Headmaster | 1 | - | 1     |
| Teaching staffs | 10 | 8 | 18    |
| Administration staffs | 5 | 5 | 10    |
| Class 7A | 25 | 13 | 38   |
| Class 8A | 12 | 10 | 22   |
| Class 8B | 11 | 11 | 22   |
| Class 8C | 11 | 10 | 21   |
| Class 9A | 10 | 10 | 20   |
| Class 9B | 10 | 10 | 20   |
| Class 9C | 10 | 10 | 20   |
| Class 9D | 11 | 10 | 21   |
| Total     | 208 |   |       |

| Dimension | Size |
|-----------|------|
| Length    | 15 m |
| Width     | 25 m |
| Height    | 18 m |
2.2. Analysis of user requirements

At this stage, coordination was carried out with the school to discuss about the required data, and development plans. While the expectations of the school related to ICT infrastructure can be described as follows. First of all, wireless network served the entire room and terrace area. Then, it was expected that library computer and laboratory were connected to the Internet. Also, users can access video. After that, two ISP links were merged into one Internet access. Subsequently, wireless network can be accessed by all students and employees; with restrictions on students only for browsing; the number of students around 130, and the employee number around 25. Finally, the Computer Lab. will be used for online-based exams.

2.3. Evaluation and re-design

At this stage, the data and information of the previous stage were analyzed, evaluated, and then used as a reference in the ICT infrastructure design. From the connection test, it showed the IP addresses of both ISPs are located at the same network identity (ID). Hence, the technique of merging wide area network (WAN) connections could not be done. In addition for bandwidth management, it needs to ensure that the speed of wireless network access is shared equally on each user's device. Based on the school development plan and field condition evaluation, ICT network planning has been prepared as Figure 3.

![Design of the ICT network](image)

**Figure 3.** Design of the ICT network

The planned configuration can be described as follows. At first, the ISP (10 Mbps) was connected to the Mikrotik router on port-1 (WAN). Then, the connection from the router was divided in two: 7 Mbps for a wired network; 3 Mbps for wireless networks; using bandwidth management techniques that combine both simple queue and per connection queue. Also, the selected wireless AP devices should have a wide range of coverage areas; function as a wireless access bridge; two wireless AP devices are arranged in series. Finally, to enable wireless networks as an extensive network, without the need to switch the service set identifier (SSID) and password when using the wireless AP. To enable roaming between wireless networks, several things to consider in configuration can be described as follows [8]. First of all, connect two access points to the same network. Secondly, make sure that there is only 1 Dynamic Host Configuration Protocol (DHCP) server. Thirdly, use the same wireless network name (SSID) for both AP's. And fourth, use the same password and encryption settings for both AP's.
2.4. Implementation

At this stage, the results of re-designing the ICT infrastructure are implemented, see Figure 4. Some parameter configurations are presented below.

The RB450G Mikrotik router configuration is described as follows. For Ether1, IP address was set to 192.168.1.5/24; and this port was connected to Telkom Speedy ISP 10 Mbps. For Ether2, IP address was set to 192.168.100.1/24. This port was connected with wired LAN. Bandwidth management was set to simple queue with 7Mbps speed limit and per connection queue. For Ether4, IP address was set to 192.168.200.1/24. This port was connected to wireless LAN. The selected bandwidth management techniques were simple queue with 3Mbps speed limit and per connection queue.

The Totolink N300RH wireless AP configuration included some parts. For operation mode was set to router mode. For LAN, IP address was set to 192.168.10.1/24. DHCP was set to server with DHCP client range from 192.168.10.2 to 192.168.10.254.

The wireless TP-Link WR841HP AP configuration included IP address for being set to 192.168.10.2/24. This device was disable for DHCP. While, IP address for DHCP ranged from 192.168.10.3 to 192.168.10.254.

![Figure 4. Room layout plan and device positions](image)

2.5. Testing

At this stage, the implementated design were tested. The choosen test device was the Sony Xperia C5303 smart phone with the WiFi Heatmap application. Figure 5. shows stages of ICT infrastructure development.

![Figure 5. Development steps](image)
When the receiver sensitivity is greater than -88 dBm, WLAN devices can receive data below the IEEE 802.11g standard [9]. For just a data network, a network can simply provide a signal with a power of -75 dBm or stronger [10]. The subsequent test results are compared and analyzed with the recommended provisions [9], [10]. Table 4 presents extensive test results on wireless LANs at various SNR levels.

| SNR (dB) | Category                  | Information                        |
|----------|---------------------------|------------------------------------|
| > 40     | Excellent signal (5 bars) | always associated; lightening fast.|
| 25 - 40  | Very good signal (3 - 4 bars) | always associated; very fast.      |
| 15 - 25  | Low signal (2 bars)       | always associated; usually fast.   |
| 10 – 15  | Very low signal (1 bar)   | mostly associated; mostly slow.    |
| 5 – 10   | No signal                 | not associated; no go.             |

3. Results and Discussion

From a series of design and development, the result is that the Internet connection from one ISP being split into two local area networks, i.e. wired and wireless networks. The selected bandwidth management techniques are the combination of both simple queue and per connection queue. The test obtains, as presented in Figure 6., the wireless LAN signal can be captured on the 1st floor with the signal strength of -45 dBm and the signal to interference ratio (SIR) of 45 dB. On the second floor, the signal can also be received with the signal strength of -40 dBm and 30 dB SIR. While on the 3rd floor, the signal can still be captured with a weak condition (-75 dBm) to be able to serve Internet-based applications, such as Whatsapp or a web browser. In addition, the channel occupied by wireless AP floor 2 is the same as the channel of wireless AP floor 1 with a power difference of 5 dB. According to Table 4, the 5 dB SNR condition is classified in "no-signal" category and is unable to service Internet applications. Possible solutions are to add a wireless AP device on the 3rd floor or shift the channel occupied by one of the wireless APs towards an idle channel.
4. Conclusion
To conclude, one ISP connection link is divided into two, the wired network is allocated 7 Mbps, and the wireless network is allocated 3 Mbps. Wireless network can serve the 1st and 2nd-floors of the school building with excellent and very good quality. While on the 3rd floor, wireless networks cannot serve Internet applications. The handover process from the 1st-floor wireless network service to the 2nd-floor wireless network runs smoothly without the need to change the SSID and password.

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