Transcending Technologies : Probing Trends and Developments in Telecommunication Systems, Dense Wavelength Division Multipexing (DWDM) for Transmission and Configurafion – A Comprehensive Review and Research Agenda

Irfan Mujahidin
Telecommunication Engineering, Semarang State Polytechnic
Jl. Prof. Sudarto, Tembalang, Semarang City, Central Java 50275, (024) 7473417
email: irfan.mujahidin@polines.ac.id

Abstract - In recent years, telecommunication systems have developed so rapidly that it has created a technology trend for transmission and configuration systems. In terms of transmission and configuration, the main trend is to increase network capacity and speed, one of which is with wireless technology. Among the various wireless technologies available, with long-range communication capabilities, increased bandwidth, increased speed, network efficiency, and cost effectiveness, Dense Wavelength Division Multiplexing (DWDM) has emerged as the most popular choice for various applications in transmission systems and configurations. This literature review aims to provide a comprehensive overview of the latest telecommunication system trends and developments in DWDM technology by reviewing existing research and identifying key challenges and opportunities for the research agenda. This review will contribute to advancing knowledge in the field of telecommunication systems especially transmission and configuration to meet the demands of evolving technologies.

Keywords: *DWDM, Telecommunication System, Transmission System, Wireless Technology*

I. INTRODUCTION

In this day and age, there are many technological developments that occur in various fields. Such as: health, agriculture, environment, transportation, and the internet. The development of the internet in this era has become so extensive that everyone can use the internet.

One of the developments on the internet is DWDM. DWDM is a fiber optic transmission technique that allows two or more wavelengths of light to propagate on a single fiber and multiple signals can be transmitted at different wavelengths in the optical spectrum.

The advantage of using DWDM technology is that it can increase network capacity because DWDM can transmit data in various wavelengths of light simultaneously through one optical fiber. And also DWDM is cost-effective because it does not require the creation of new infrastructure, but can use existing infrastructure.

Many studies aim to develop DWDM technology. In the research "A new generating carrier for THz communication by the nonlinear microring resonator systems" aims to propose a new design and to demonstrate the optimized results of light pulse simulation in the micro ring resonator system.

The research "A High Sensitive Micro-Seismic Fiber Bragg Grating (FBG) Sensor System" aims to develop a micro-seismic FBG sensor system and improve the efficiency and accuracy of microseismic monitoring. And also other examples regarding the development of DWDM technology.

However, although DWDM has enormous advantages and potential. The transmitters and receivers made have complicated structures. For low channels it is not cost-effective because DWDM is used for high channels so When using low channels it is recommended to use other WDM.

In addition, DWDM uses specialized devices and infrastructure so that when you want to install and maintain these devices, you need experienced experts. Also, DWDM is difficult to change due to its specialized devices and infrastructure, which adds cost and complexity. This literature review aims to show a wide range of research on DWDM from various international journals by surveying and combining the selected research.

This literature review will investigate the objectives, problems, methods, and conclusions of the selected research on the development of DWDM technology .

By examining and identifying the selected research, it will increase the knowledge of DWDM and make it possible to develop DWDM at a higher scale and performance.

II. THEORY BASIC

A. Dense Wavelength Division Multiplexing

Dense Wavelength Division Multiplexing (DWDM) is a fiber optic technology that is useful for distributing data with a large capacity, the way DWDM works is by making various frequencies of light sent combined into 1 light wave which produces

various channels which will then be channeled back through 1 cable at the receiving end to be parsed back into the transpoder.

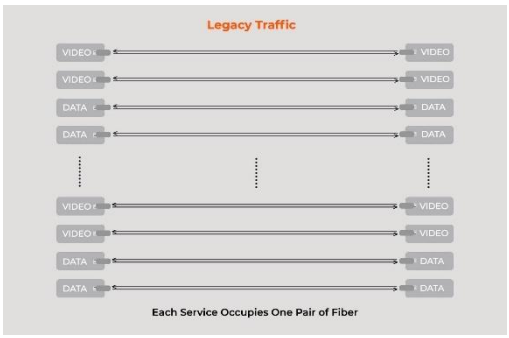


Fig 1. The working principle of DWDM technology with one service in one pair

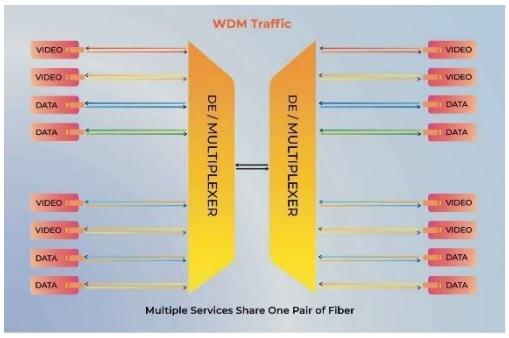


Fig 2. Working principle of DWDM technology with multiple services in one pair

This is done with DWDM technology because multiplexer and demultiplexer devices of each different wavelength of light carry specific data.

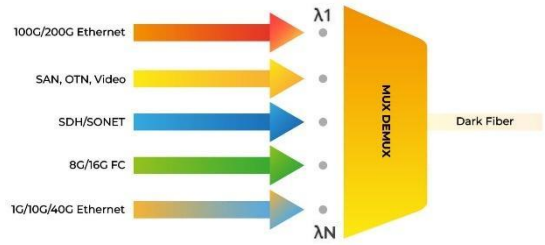


Fig 3. Different wavelengths of Light as transmitted data carriers

In daily use, DWDM networks are usually used to provide a medium for channeling data communication traffic between data centers such as between cities and countries, and also DWDM can improve network services.

B. Telecommunication System

Telecommunication system comes from the words "system" and "telecommunication". The word "system" refers to a unit consisting of inputs that are processed and produce outputs. While the word "telecommunication" can be interpreted as a conversation between 2 or more people at a distance. So it can be concluded that a telecommunication system is a system used to serve conversations between 2 people from a distance.

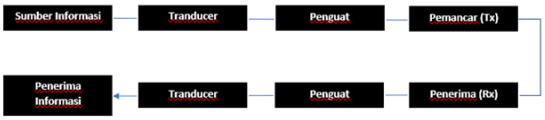


Fig 4. Block diagram of Telecommunication System

In this case there are 4 types of communication, namely point to point communication is a process of 2 people connecting with each other like two people on the phone. Point to multipoint is the process of interaction between sender and receiver where the sender can send a lot of information at once to many recipients such as teleconferencing. Broadcasting is where the sender sends information to the receiver but cannot interact with each other such as radio and television transmitters. Simplex communication is a type of communication that has only one transmitter and one receiver. Simplex communication cannot be used for radio or television broadcasting. Half-duplex communication refers to a kind of communication that can be performed in real time. However, half duplex communication can only use one transmission channel so the communication must take turns like a walkie talkie system. Full duplex communication is communication that can be done simultaneously between the caller and the called freely on 1 transmission channel such as telephone.

III. METHOD AND DESIGN

This research uses the Systematic Literature Review (SLR) method or can be interpreted as a systematic literature review. Systematic Literature Review (SLR) has several processes, namely determining, evaluating, and analyzing existing research to gain knowledge and answer research questions.

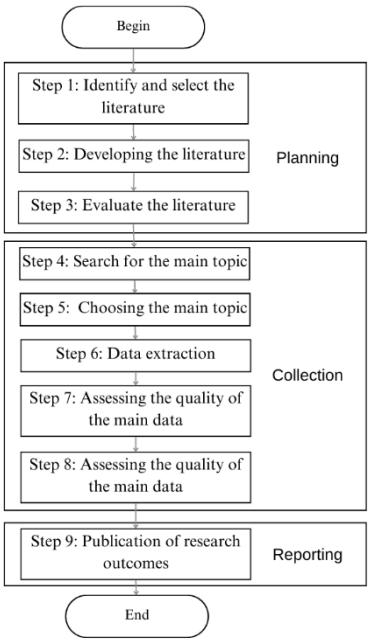


Fig 4. Steps of a systematic literature review

The population data of this study are journals that focus on trends and developments in telecommunications systems for transmission and configuration in DWDM. There are 22 articles from international journals that will be selected as literature to be reviewed. This SLR has 3 stages, namely Planning, Implementation, and Reporting which can be seen in Figure 4.

The first thing to do is to conduct identification by completing a comprehensive literature review with due regard to trends and advancements in telecommunications systems,especially DWDM technology for transmission and configuration. The next stage is to Following the SLR protocol to cut down on any potential transparency bias in the study involving a few key process steps. Then formulating a research question followed by a study search process. Next, selecting the studies using the inclusion criteria and exclusion criteria formulated earlier. The next step is to screen the selected studies to obtain quality and relevant data. The last step is reporting by compiling a research report based on the SLR protocol that has been established with a discussion so that conclusions can be drawn from the information that has been collected.

A. Research Question

These research questions ensure that the SLR is fit for purpose. The research questions will be structured using the PICOC guidelines which include Criteria (P), Intervention (I), Comparison (C), Outcome (O), and Context (C). Table 1 shows the PICOC structure of the research questions (RQs) in the systematic literature review on trends and developments in telecommunication systems for transmission and configuration.

Table 1. PICOC Summary

Populasi (P)	DWDM sebagai salah satu teknologi untuk transmisi dan konfigurasi
Intervensi (I)	Tren dan perkembangan system telekomunikasi
Perbandingan (C)	Tidak ada
Hasil (O)	Memahami, meningkatkan, serta mengembangkan tren dan perkembangan system telekomunikasi teknologi DWDM
Konteks (C)	Transmisi dan konfigurasi menggunakan teknologi DWDM

The research questions (RQs) formulated in the study are in the following table.

Table 2 Research Question on Literature Review

No	Research Question (RQ)	Action
RQ 1	What are the most published journals on DWDM technology trends and advancements for transmission and configuration?	Identify the journals that discuss the most trends and developments in DWDM technology for transmission and configuration
RQ 2	Who are the most influential and active researchers in DWDM technology for transmission and configuration?	Identifying the most active and influential researchers in DWDM technology trends and developments for transmission and configuration
RQ 3	What is the reliability of DWDM technology for transmission and configuration?	Knowing the extent to which DWDM technology is reliable in supporting data transmission with increased transmission capacity.
RQ 4	How does DWDM technology perform in terms of coverage and signal strength?	Understand how much DWDM technology can span large geographic areas and provide strong signals to support applications and transmission system configurations.
RQ 5	Does DWDM technology have high capacity?	Evaluate the efficiency level of capacity usage in DWDM technology networks to optimize existing optical fibers.
RQ 6	Is DWDM technology cost-effective?	Evaluate the cost-effectiveness of DWDM technology for transmission and configuration.
RQ 7	Where can DWDM technology be applied in transmission systems and configurations?	Identify journals that are a form of application of DWDM technology, especially in transmission systems and configurations.

The main questions in this systematic literature review focus on questions RQ 3 - RQ 7. These questions help direct the research focus and better understand the trends and developments in telecommunication systems specifically DWDM technology for transmission and configuration. Meanwhile, the research questions on RQ 1 - RQ 2 will assist researchers in evaluating the main research context and provide information regarding the summary and synopsis of research areas related to DWDM technology for transmission and configuration systems.

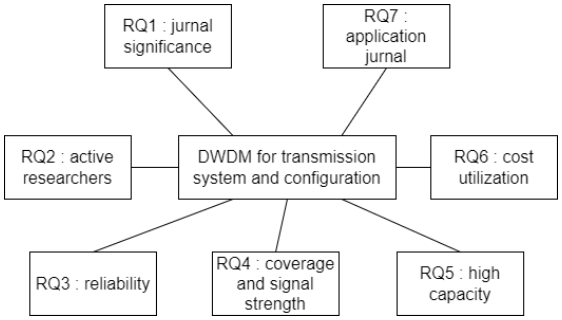


Fig 5. SLR mind map of Transcending technologies : probing trends and developments in telecommunication systems, Dense Wavelength Division Multipexing (DWDM) for transmission and configurafion

The main objective of this research is to understand and enhance knowledge regarding trends and developments in telecommunication systems, particularly DWDM technology. Thus, this research is directed to provide an understanding of the reliability, coverage, network efficiency, cost effectiveness, and various applications of DWDM technology in transmission systems and configurations. The mind map of this systematic literature review can be seen in Figure 5.

B. Research Strategy

The fourth step in a systematic literature review involves a search process that consists of several steps. These steps include selecting a digital library, searching for search keywords, filtering search keywords, and retrieving important research data from the digital library. This process ensures that the search is effective so Before embarking a research, proper data selection was done to find the most relevant articles. The website used in the digitizing search is Semantic Scholar (https://www.semanticscholar.org/).

The keyword search in this systematic literature review followed the following steps: define search terms derived from the PICOC framework focusing on population (P) and intervention (I) sections; identify search terms relevant to the research question (RQ); identify search terms relevant to the title, abstract, and predefined keywords; identify synonyms, antonyms, and spellings associated with the search terms; perform search filters such as AND and OR. Example: (Telecommunication systems and DWDM). The objective of these keywords is to get as many relevant articles as you possibly can on the topic you are currently studying.

C. Course selections

During the process, the exclusion and inclusion criteria for selecting the principal study are explained in the following table 3.

Table 3. Inclusion and Exclusion criteria in SLR

Inclusion criteria	- Research articles using technologies that are based on knowledge of DWDM - The research articles included are preferably Scopus indexed journal articles. - Only most comprehensive and latest publications will be considered for duplicating papers from the identical research..
Exclusion criteria	- Articles only focus on nontechnical aspects such as social or business in DWDM. - Research that only focuses on theoretical or conceptual aspects without any real implementation of DWDM research results. . - Research that is not relevant to DWDM scalability and performance.

Mendeley was used as a reference manager that managed search results and saved searches. The study selection process consisted of 2 stages: exclusion by title and abstract, and then a thorough examination of the full text.

D. Data Extraction

This step consisted of the extraction of the collected articles' information and the systematic entry of it into the table. The summarization of data was classified based on the research queries and the analyzed conducted by the researcher, as displayed in the following Table 4.

Table 4. Data Extraction

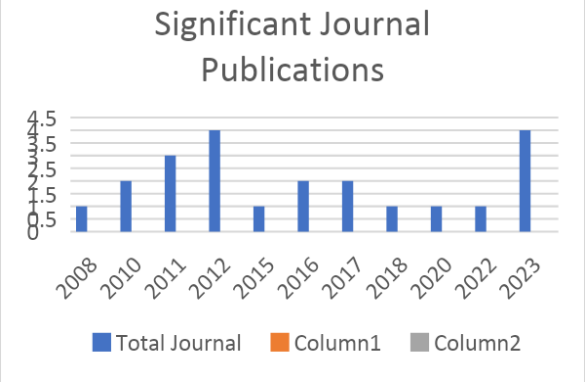
Asset	The question of research
Identification and Publication	RQ1, RQ2
Reliability	RQ3
Performance	RQ4
Capacity	RQ5
Cost	RQ6
Journal of Application	RQ7

E. Study Quality Assessment and Data Synthesis

It is used as a manual in synthesizing the data to identify the power of the results and eliminate bias. Data synthesizing aims to collect data to respond the research inquiries of the selected studied. The structure used in this data analysis was the method of narrative. Data were consistently organized based on the research question. The visualizations such as bar diagrams, pie graphs, graphs, curve, and tables were employed to illustrate the development and trends in telecommunication systems, specifically DWDM technology for both transmission and configuration.

IV. RESULTS AND DISCUSSION

A. *Significant Journal Publications*



Graph 1. Contribution of Trends and Developments in Telecommunications Systems, especially DWDM Technology for Transmission and Configuration

In the graph, it can be seen that the year that has contributed to the trend and development of telecommunications systems, especially DWDM technology for transmission and configuration, is the most in 2023, followed by 2012 and 2017.

B. *Most Powerful and Engaging Researchers.*

From the literature that have been selected, researchers discussing DWDM technology for transmission systems and configuration have actively researched the issues, risks, and constraints associated with DWDM technology for transmission systems and configuration. From the selected data, it was found that Ricky Anthonya, Sambhunath Biswasa, A. Polar, German V. Arevalo, Roberto C. Hincapie, Roberto Gaudino, Sarath Ganga Sa, Asha R Sa, and Shaija P Ja are some of the researchers who have used DWDM technology for transmission and configuration systems the most.

C. *Research Topic*

DWDM performance is an important research topic in the study of telecommunication technologies that focus on data transmission using light. Some selected research on DWDM reveals that the things analyzed in DWDM performance focus on five topics: Identifying DWDM performance problems and solutions to existing problems, finding the risks and efficiency of implementing further development of DWDM, classifying the use of DWDM in various fields, optimizing the performance of DWDM use, and analyzing the literature using DWDM technology.

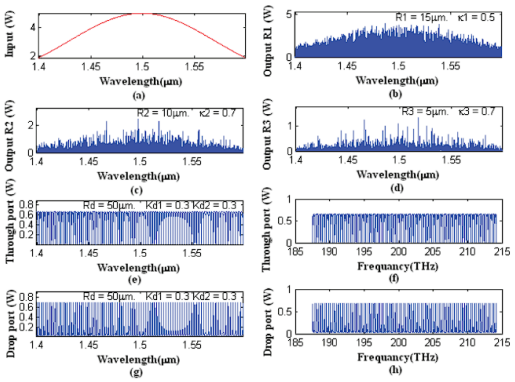
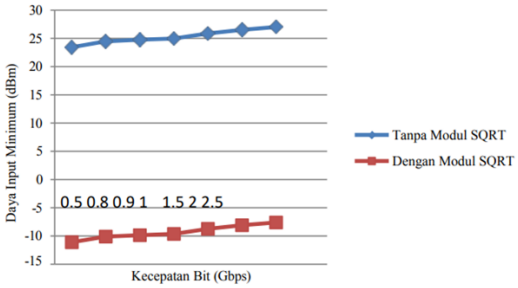


Fig 6. Output of Ring Resonator System with Center Wavelength of 1.5 μm in Research [5]

In [5] research resulted in the generation of a single THz carrier with a FWHM of 0.2618 THz using the proposed photonic system. The THz frequency components generated by the system were analyzed and optimized to improve performance. In [4] research resulted in the proposed techniques and strategies effectively reducing fragmentation and bandwidth blocking in elastic optical networks. The authors can show that their approach leads to improved network performance and reduced bandwidth blocking rates. In [6] results in a protection for each request and to make the entire network load balanced with respect to routing options and enable better performance. In research [7] Outcome When the optical fiber Nanotechnology is implemented in the transmission of power communication, the loss of the communication cable is well within allowable limits, and the stability of the system is increasingly manifest. In the research [25] produced the use for high performance monitoring, low-power magnetic switch logic, quantum logic, quantum gate, nano antenna, nano radio, and spintronic sensing applications can be recognized based on reasonable device options. It can be seen that DWDM technology is reliable in supporting data transmission with increased transmission capacity.



Graph 2. Minimum Transmission Power V/S Bit Rate in Research [8]

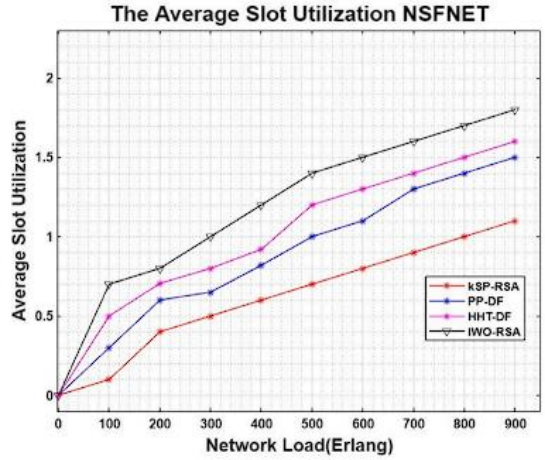
Format Modulasi	Faktor Q (dB)	BER
NRZ	6.722	8.949*e-012
RZ	5.116	1.548*e-008
Kosinus Terangkat	5.014	5.014*e-007
Gaussian	5.810	3.115*e-009
Sinus	4.990	2.976*e-007

Table 5. Comparison of Modulation Formats in Research [8]

Filter	Faktor Q (dB)	BER
Bessel	6.722	8.949*e-012
Persegi panjang	5.328	4.930*e-005
IIR	5.481	2.110*e-008
Gaussian	6.100	5.277*e-010
Kosinus Terangkat	5.95	1.281*e-009
Cosinus Roll off	6.09	5.363*e-010
Kuadrat Kosinus Roll off	5.95	1.285*e-009

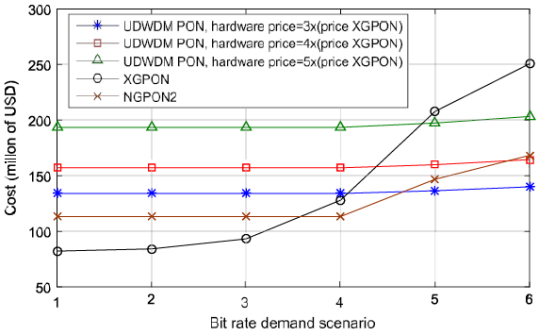
Table 6. Comparison of Filter Performance in Research [8]

In [8], the proposed techniques and strategies effectively reduce fragmentation and bandwidth blocking in elastic optical networks. The authors were able to show that their approach leads to improved network performance and reduced bandwidth blocking rates. In [9], it was found that the NNRR system can be used to generate soliton pulses with an FSR of 0.052 nm. This is significantly smaller than the FSR of current communication systems. The research [10] results most likely include performance evaluation of wavelength conversion systems, such as conversion efficiency, signal quality, and other related parameters. It can be seen that how much DWDM technology can cover a wide geographical area and provide strong signals to support transmission system applications and configurations.



Graph 3. Average FS Utilization of Networks in Research [11]

Research [11] resulted in the efficiency of spectrum allocation and routing in elastic optical networks. Simulation results show that the proposed algorithm can produce the expected solution to routing, spectrum allocation, and fragmentation problems in elastic optical networks. In the study [12] resulted in EDFA gain spectrum. It is proven to possess dynamic range variations for each informational channel in conjunction with saturation impacts, hence restricting the total number of channels allowed for telecommunications. along with saturation effects, thus limiting the total This study provides a comprehensive understanding of the temperature-dependent performance of EDFA and develops strategies to reduce the effects of temperature variations on its performance in optical communication systems. In [13], a new system to generate optical communication in the terahertz (THz) frequency band for RFID applications was produced. The proposed system has shown optimized results with various RFID applications. In research [14] producing the multiplexed signal can be performed by the use of a long-wavelength router and transforming it into the frequencies domain within a single and equivalent system, being allowed to pick up radios on multi-channel fiber applications. It can be seen that the level of efficiency of capacity usage in DWDM technology networks to optimize existing optical fibers.



Graph 4. Price Comparison of PON Technology in Research [15]

In research [15] results in NGPON2 prices are almost always constant, there is a point where it intersects with the XGPON and NGPON2 curves The intersection represents an approximate scenario where the NGPON2 solution is a better choice than other PON technologies. In [16], QWI has the potential to reduce the cost and complexity of PIC fabrication. It can be seen that the level of cost-effectiveness used in DWDM technology for transmission and configuration.

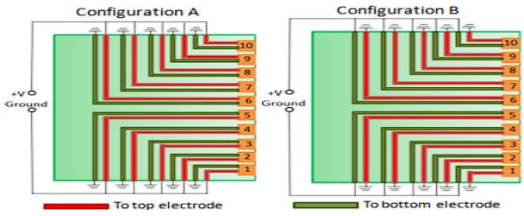
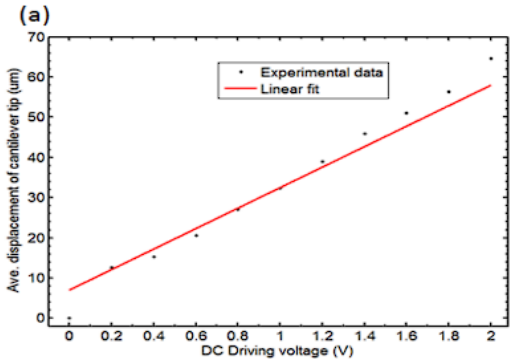


Fig 7. Schematic Drawing of Refraction Configurations A and B to Induce Bending Nodes in Research [18]



Graph 5. Average Measured Displacement of Ten Actuators under Bias in Research [18]

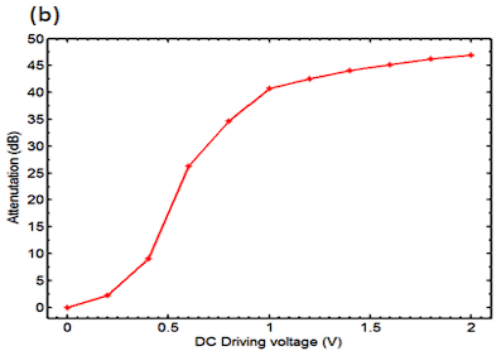
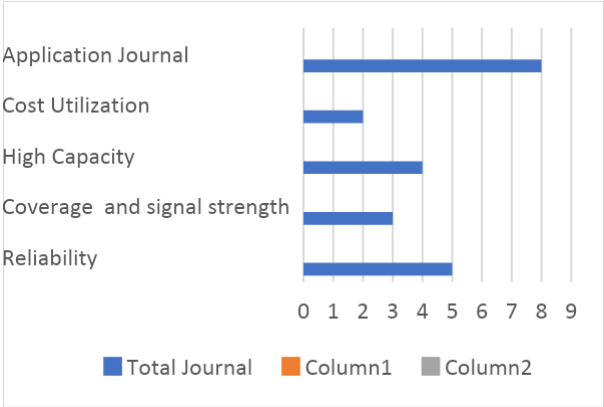


Figure 6. The Rated attenuation Vs DC Driver Voltage Deployed to all the Actuators Used Bias Configuration A in the Study [18]

In the research [18] generated a wavelength multiplexing (MUX) and demultiplexing (DMUX) unit of a dense wavelength division multiplexer (DWDM) systems to control the optical signal transmission power. In research [17] produces Demonstrate the feasibility and effectiveness of high sensitive microseismic FBG sensor systems in detecting and monitoring micro-seismic signals with high accuracy and fast response. In research [19] produces coding that uses Gaussian pulses with a center wavelength at 1,550 nm and bringing the high-capacity line and multi-switching system in the system of optical networks for the direct link among optical terminals or the connection through relay node. In research [20] results in UH and CH privacy amplification schemes can effectively reduce information leakage to eavesdroppers and reduce the effects of quantum channel noise in a quantum router environment and the CH scheme outperforms the UH scheme in terms of security, especially in scenarios with high probability of eavesdropping and noisy quantum channels.... In research [21] results in Wavelength is much more pronounced for thin sheets, so the industrial center cutting laser machine was more efficient in slicing thin strips than the CO2 variant of the laser. In research [22] produces The importance of power allocation in adaptive WDM transmission in RoFSO to reduce the effects of weather turbulence and improve the performance of WDM RoFSO systems. In research [23] produces practical rules for planning Edge-to-edge Latency to analyze and overview some latency management approaches for frontier traffic. In research [25] produces moderate refractive index values and center wavelengths that are appropriate and accurate. It can be seen that this journal is a form of application of DWDM technology, especially in transmission systems and configurations.

D. Characteristics of DWDM Technology Use in Telecommunication Systems

Journals from trends and developments in telecommunications systems, especially DWDM technology for transmission and configuration, grouped 22 journals that fit the predetermined characteristics.



Graph 7. Characteristics of Trends and Developments in Telecommunication Systems especially DWDM technology for transmission and configuration

E. Research Agenda

The Research Agenda discusses the development of dwdm whose results show the speed and how much data capacity can be optimized by examining the overall range of consumption and energy costs and innovations that can be made so that in the future dwdm can be used not only in other fields. DWDM has the advantage of being able to transmit multiple light wave signals at various wavelengths simultaneously, thus increasing network capacity significantly. By utilizing a wide spectrum of light, DWDM enables the transmission of large amounts of data at high speeds, supporting increased network throughput without the need to add physical optical fibers. Nonetheless, some disadvantages of DWDM need to be considered. One of them is the complexity of light spectrum management and signal isolation, which can be a challenge in network management. To improve efficiency and performance, it is necessary to focus on developing technologies to address these complexities, including innovations in spectrum management and signal isolation techniques. In addition, improved real-time performance monitoring and increased network resilience to interference can also be the focus of improvements to enhance DWDM reliability under various operational conditions.

Therefore, by continuing to address these weaknesses, 2 2 2 6 10 8 DWDM can continue to be a highly efficient and reliable solution to meet the needs of high-capacity optical network infrastructure. The cost of installing and maintaining a Next Generation Passive Optical Network (NGPON 2) and Ultra-Dense Wavelength Division Multiplexing Passive Optical Network (UDWDM PON) in a residential environment involves a number of factors, including network design, existing infrastructure, hardware and software, construction work, labor, maintenance, licensing, permits, testing, and project scale. These costs may vary based on location, project size, and other local factors. It is recommended, to get a more accurate cost estimate, to coordinate with local service providers or contractors who have experience in implementing this technology in a residential setting. FBG is an optical sensor used to measure variations in wave speed on optical fibers, FBG is also used in various applications such as temperature sensors, pressure sensors, and other sensing applications. By combining Micro seismic with FBG, a sensor is created that can detect and monitor micro seismic signals with high accuracy and fast response. Micro seismic FBG overcomes the challenges of micro seismic monitoring, providing reliable and high sensitivity in low frequency seismic acquisition. However, there is a need for further development using WDM technology to improve the sensitivity and measurement capacity of microseismic FBG systems that can respond quickly in detecting microseismic signals. WDM also allows the coupling of seismic signals from multiple FBG sensors into the same optical fiber, enabling high-resolution seismic monitoring across the network thereby increasing network capacity while maintaining the sensing capability to monitor along the fiber path.

V. CONCLUSION

developments in telecommunication systems for transmission and configuration in DWDM were selected according to the predetermined inclusion and exclusion criteria. This literature review uses Systematic Literature Review (SLR) which requires identification, evaluation, and understanding of all research results used to answer questions that arise during the research process. Research on DWDM performance focuses on several aspects of research, namely long-distance communication capabilities, increased bandwidth and speed, as well as network efficiency and resulting costs. DWDM technology has been widely used in various aspects, such as health, agriculture, environment, transportation, and the internet. It is proven that DWDM can increase the capacity of networks that can transmit data in a variety of wavelengths. The cost generated when installing DWDM is also not much because DWDM does not require new infrastructure for the installation process. Based on the research that has been done, DWDM has characteristics that are suitable for use in the development of telecommunications systems, especially in wireless network technology.

VI. REFERENSI

[1] Apa Itu DWDM dan Keuntungannya Bagi Perusahaan? — Link Net. (n.d.). Apa Itu DWDM Dan Keuntungannya Bagi Perusahaan? — Link Net. https://www.linknet.id/article/apa-itu-dwdm-dan-keuntungannya-bagi-perusahaan

[2] Team, I. (2022, August 11). Mengenal teknologi DWDM sebagai media penyaluran trafik komunikasi data kapasitas besar - INDONET. INDONET. https://indonet.co.id/mengenal-teknologi-dwdm-sebagai-media-penyaluran-trafik-komunikasi-data-kapasitas-besar/

[3] Wardhani, T. a. H. (2022, January 15). Pengenalan Dasar Sistem Telekomunikasi - Griya Website dot com. Griya Website Dot Com. https://www.griyawebsite.com/pengenalan-dasar-sistem-telekomunikasi/

[4] N., Kitsuwan., & K, Akaki. (2023). Performance of elastic optical network with limited slicers. *ICT Express*, 362-365

[5] P, Eakkapan,, S, Somkuarnpanit., N, Pornsuwancharoen., & P, P. Yupapin. (2012). A new generate carrier for THz communication by the nonlinear microring resonator systems. *Procedia Engineering*, 468-474

[6] S, Punthawanunta., P, P. Yupapin., X Louangvilayc., & S, Mitathad. (2011). Quantum CNOT Gate Operation using Dark-Bright Soliton Pair. *Procedia Engineering*, 445-450

[7] H, Yu., P, Li., L, Zhang., Y, Zhu., F, A. Al-Zahrani., & K, Ahmed. (2020). Application of optical fiber nanotechnology in power communication transmission. *Alexandria Engineering Journal*, 5019-5030

[8] N, Sangwaranatee., N, W. Sangwaranatee., C, Teeka., & P, P. Yupapin. (2012). All-Optical Nanoscale Microring Device and System Design for Nano Communication. *Procedia Engineering*, 509-515

[9] M, S. Aziz., A, Afroozeh., M, S. Roslan., M, A. Jalil., I, N. Nawi., J, Ali., & P, P. Yupapin. (2011). Capacity Enhancement in Communication System via NNRR. *Procedia Engineering*, 407-411

[10] M, J. Kappen., R, S. Asha., & T, Binesh. (2016). 10 Gbps externally modulated XGM based wavelength conversion using SOA. *Procedia Technology*, 25, 560-566

[11] S, S. Kumar., S, Kalaivani., S, S. Ibrahim., & G, Swathi. (2023). Traffic and fragmentation aware algorithm for routing and spectrum assignment in Elastic Optical Network (EON). *Optical Fiber Technology*, 103480

[12] R, Anthony., & S, Biswas. (2012). Temperature dependent gain analysis of a cascaded C-band EDFA DWDM network. *Procedia Technology*, 92-96

[13] B, Sansoda., S, Thongmee., N, Pornsuwancharoen., P, P. Yupapin., & R, Phromloungsri. (2012). A New THz Frequency Band Generation for Optical radio System of RFID Applications. *Procedia Engineering*, 502-508

[14] N, Pornsuwancharoen., K, Boonmeewised., N, Kitcharoen., B, Sansoda., P, P. Yupapin., & R, Phromloungsri. (2012). A novel optical radio on fiber multi-channel by micro ring resonator system. *Procedia Engineering*, 45-52

[15] G, V. Arévalo., R, C. Hincapié., & R, Gaudino. (2017). Optimization of multiple PON deployment costs and comparison between GPON, XGPON, NGPON2 and UDWDM PON. *Optical Switching and Networking*, 80-90

[16] L, Hou., & J, H. Marsh. (2016). Photonic integrated circuits based on quantum well intermixing techniques. *Procedia Engineering*, 107-114

[17] J, Y. Wang., G, D. Song., X, H. Liu., C, Wang., & T, Y. Liu. (2011). A High Sensitive Micro-Seismic Fiber Bragg Grating (FBG) Sensor System. *Procedia Engineering*, 765-771

[18] K, H. Koh., C, Leea., & T, Kobayashi. (2010). A 3-D MEMS VOA using translational attenuation mechanism based on piezoelectric PZT thin film actuators. *Procedia Engineering*, 613-616

[19] A, Polar., M, Bunruangses., K, Luangxaysanam., S, Mitatha., & P, P. Yupapin. (2012). Overlay Fiber Network Based MNRs for P2P Networks. *Procedia Engineering*, 482-488

[20] S, Chaiyasoonthorn., P, Youplao., S, Mitatha., & P, P. Yupapin. (2012). Privacy Amplification of QKD Protocol in a Quantum Router. *Procedia Engineering*, 536-543

[21] G, C. Rodrigues., V, Vorkov., & J, R. Duflou. (2018). Optimal laser beam configurations for laser cutting of metal sheets. *Procedia CIRP*, 714-718

[22] H, Zhou., S, Mao., & P, Agrawal. (2015). Optical power allocation for adaptive transmissions in wavelength-division multiplexing free space optical networks. *Digital Communications and Networks*, 171-180

[23] D, Larrabeiti., L, M. Contreras., G, Otero., J, A. Hernández., & J, P. Fernandez-Palacios. (2023). Toward end-to-end latency management of 5G network slicing and fronthaul traffic. *Optical Fiber Technology*, 103220

[24] W, Chong. (2011). A Depolarization Method to Seek The Suitable Refractive Index Value of The Middle Layer in Oblique Incidence. *Procedia Engineering*, 2170-2174

[25] N. Sangwaranatee, N. W.Sangwaranatee, C. Teeka, P.P. Yupapin. (2012). All-Optical Nanoscale Microring Device and System Design for nano Communication. *Procedia Engineering*, 509-51