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A REVIEW OF FI-WI ACCESS NETWORKS

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ABSTRACT

The explosive growth of information and communication technology necessitates an access solution that can provide customers with faster Internet speeds "anytime, anyplace." Fiber Wireless (Fi-Wi) access technology is one of the available options for meeting consumers' current needs in a cost-effective manner. ONU deployment and energy conservation are two crucial aspects of the Fi-Wi network. The issue of ONU placement has an impact on deployment costs and network performance, while energy conservation is a requirement for green technology. Fi-Wi networks are quickly maturing, and latest effective access network technologies and concepts are emerging. The study begins by reviewing the current state of wireless access optical and optical networks, as well as enabling technologies and future developments, with a major vision on wireless mesh networks and fibre to the base networks. Following a brief overview of several generic EPON and WiMAX network integration approaches, some recently proposed Fi-Wi designs concepts on different Wi-Fi technologies and optical network topologies are detailed. Ultimately, technical hurdles in realising and commercialising future Fi-Wi access networks are identified.

KEYWORDS: *Fiber Wireless, Networks, Optic, Architecture*

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1. INTRODUCTION

The Cyber space and interaction networks' decisive goal is to aid access to data when it is required, where it is required, and in all that structure we require it. Optical technologies and wireless technologies and are very much essential to achieving this objective. Wireless and optical access networks are complimentary in nature. Optical fibre does not reach every position, but where it makes, it offers a massive quantity of bandwidth. Wireless access networks, alternatively, have the ability to go practically universally, but they afford a bandwidth-restricted transmission channel that is vulnerable to a diversity of glitches. Upcoming broadband access networks must clearly achieve both tools and converge them effortlessly, delivering (Fi-Wi) fiber-wireless access networks, since providers must meet customers with ever increasing capacity demands.

Fi-Wi Access Network (Fi-Wi) is intended as a leading and beneficial next-generation fusion access network. Fi-Wi Access Network associates wireless access technology with optical access networks to deliver both technologies' possible aids. In a Fi-Wi network, the Optical Network Unit (ONU) placement problem is critical because it allows for effective network resource usage and improves the performance in relationships of cost effectiveness and output. Figure 1 depicts the Fi-Wi Network's architecture.

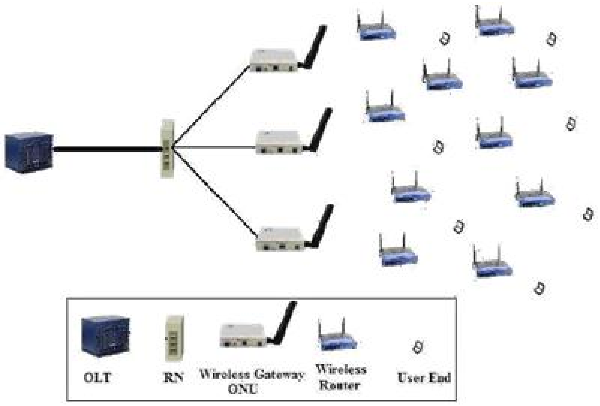

Figure 1: The architecture of Fi-Wi Network.

Passive optical network (PONs), which acts with a diversity of wireless access approaches, could be measured the last leading edge of optical fibre to the household (FTTH) or adjacent to the issue (FTTX) networks. (RoF) Radio-over-fiber networks remain one attractive way to combine wireless and optical fibre networks. IEEE 802.11 is wireless local area network (WLAN), Wideband code-division multiple access (WCDMA), Phone system (PHS), and Worldwide Scheme for Mobile Communications (GSM) are amongst the digital formats and wireless technologies that RoF networks may implement cost-effectively [1]. The smooth mixing of RoF methods with present and developing optical access networks, includes FTTX and wavelength-division multiplexing networks, is critical for future multiservice access networks. In cellular networks, RoF networks are likewise ideally altered to evade common handovers of speeding users. The practice of an optical fibre WDM ring created RoF net deployed sideways the railway tracks in linking through the travelling cell concept, as newly planned in [2] is an exciting way to evade conveyances for train customers. Affecting cells allow a cell design and a train to travel on the equivalent radio frequency diagonally the relationship in a synchronised method not including the need for handovers.

We'll assume that the optical fibre covers the road to and enters residential and corporate clients' residences. We discuss the closing edge of optical networks: conjunction along with their wireless complements, arguing that optical fibre is probable to completely substitute copper cables in the nearby to long-term due to its unique features. Over the next few decades, optical and wireless knowledge are predictable to collaborate. Forthcoming broadband access networks will be of dual mode, leveraging both technologies' capabilities and intelligently combining them to create future proof Fi-Wi Access Network that boosts our info society while avoiding the digital rift. Fi-Wi Access Network create a formidable foundation for secondary and generating existing as well as upcoming unexpected applications and services by joining the power of optical fibre networks with the omnipresence and flexibility of wireless networks.

By replacement commuting with teleworking, Fi-Wi Access Network has the probable to convert the way we work. This not only releases up time for work and private pursuits, but it also helps to minimise fuel use and shield the environment, both of which are pretty progressively significant in our existence [3].

We present-day an up-to-date review of Fi-Wi networks in this post. We focus on allowing skills and intricate on emergent Fi-Wi designs, as well as observe their future problems, after investigative state-of-the-art optical access networks and temporarily outlining forthcoming advancements in both fields.

2. OPTICAL ACCESS NETWORK

Optical fibre has much more bandwidth possibilities than wireless or any other recognized transmission method. Information can be transmitted at a rate of 25,000 GHz over a single strand of fibre. More significantly, optical networks are well suitable to optical bypassing electronic equipment, as well as lessening their footprint, difficulty and power utilization while retentive optical openness through data rate, adjustment format and procedure.

2.1 FTTX Networks

The subsequent big thing in optical fibre communications is likely to be FTTX networks. Future FTTX access networks must provision extensive range of novel and developing services and tenders, including three-way, video on request, point-to-point (P2P) audio/video file distribution and spilling, multimedia/multiparty, multi-channel HDTV, games through, and telecommunications, in addition to eliminating the first/last mile bandwidth blockage among bandwidth-starving culmination handlers and high-speed mainstay networks. Since of their extended life, little reduction, and massive bandwidth, PONs is often utilised to make budget-efficient FTTX access networks [4].

2.2 PONS

Multiple PONs has typically single-channel time-division multiplexing (TDM) structures, with a solitary upstream wavelength channel and a single downstream wavelength channel carried via the fibre infrastructure (from a fundamental business office to contributors). The IEEE 802.3ah Ethernet PON (EPON) through a symmetrical contour rate of 1.2 GB/s and the International Telecommunication Union — Telecommunication Standardization Sector (ITU-T) G.98 Gigabit PON (GPON) through an ambitious contour proportion of 1.24 GB/s and a downstream contour proportion of 2.48 GB/s characterise existing state-of-the-art commercially presented and generally positioned TDM PON access networks GPON brings powerful operation, management, preservation, and provisioning (OAMP) capabilities, as well as downstream traffic safety via encryption employing Advanced Encryption Standards at the protocol level. Furthermore, employing the GPON encapsulation technology, GPON professionally quarters traffic combines including not even asynchronous transfer mode (ATM) units and also TDM (voice) and adjustable-volume packets (GEM). EPON promises to combine Ethernet's minimal-cost apparatus and minimalism with PONs' minimum-cost organization. Protection and OAMP are not stipulated in the EPON standard IEEE 802.1ah, still they can be applied utilizing the DOCSIS OAMP facility layer on upper of the EPON MAC and PHY layers. Given that 95% of LANs use up Ethernet, and that most requests and video) are migrating to Ethernet, EPON is predictable to develop the norm in the near future.

PONs are single-channel time-division multiplexing (TDM) systems having a solitary upstream wavelength channel (from customers to a central office) and a single downstream wavelength channel transported across the fibre infrastructure (from a central office to customers). The present state-of-the-art obtainable in open market and extensively organised TDM PON access networks are IEEE 802.3ah Ethernet PON (EPON) through a balanced contour proportion of 1.2 GB/s and ITU-T G.984 Gigabit PON (GPON) through an upstream contour proportion of 1.24 GB/s and a downstream contour proportion of 2.487 GB/s, but standardisation exertions have previously been started in the IEEE 802.1av Task Force GPON delivers powerful operation, management, maintenance, and provisioning (OAMP) features, as well as downstream traffic security through encryption at the protocol level using Advanced Encryption Standards. Additionally, the GPON encapsulation technique effectively manages traffic mixes that include not just ATM cells however also TDM (voice) and adjustable-amount packets. EPON aims to combine the minimal-cost apparatus and minimalism of Ethernet together with the minimal-cost infrastructure of PONs. The EPON standard IEEE 802.3ah does not include security or OAMP, but these can be implemented using the DOCSIS OAMP service layer on top of the EPON MAC and PHY layers. EPON is predictable to develop the norm in the near future, given that Ethernet is used in 95% of LANs and that greatest appliances and customer services (such as video) are migrating to Ethernet.

EPON and GPON are thought to convey a single wavelength channel in each direction in most circumstances. However, as defined in ITU-T Reference G.984.1, this establishes an enrichment band from 1538 to 1565 nm as well as an L-band retained for upcoming practices, the bulk of real-world PON operations utilize a supplementary down-stream wavelength channel for video delivery. The improvement band and L-band be able to utilized to permit supplementary services such as overlaying multiple PONs on a single fibre infrastructure or optical time domain reflectometry (OTDR) for analysis and troubleshooting.

3. FI-WI NETWORKS

Presently, dual methodologies utilized to execute fiber-wireless networks are:

- Free space optical (FSO), also recognized as optical wireless (OW)
- Radio over fiber (RoF)

Free space optical is a sort of straight line-of-sight (LOS) optical connections that uses visible or infrared (IR) beams to offer point-to-point connections [5]. It has a wide band width and can connect constantly across short distances. A great-power glow radiating diode (LED) or else optical maser diode is used to make the transmission carrier, though the recipient may use a simple photo indicator. FSO structures presently carry out in full-duplex method with speeds ranging from 100 Mb/s to 2.54 GB/s, depending on weather conditions. FSO communications can work over numerous kilometres if there is a clear line of sight among source and destination and appropriate transmitter power. Optical fibre is used to establish great-speed LANs, like Gigabit Ethernet (GBE), at both the source and destination.

Radio over fiber, permits a moderated radio frequency (RF) signal to be transmitted via an analogue optical link. Radio over fiber networks can be formed using a diversity of ways. One way order to improve the transmission range, a Radio over fiber transmitter often uses a Mach-Zehnder intensity (MZI) modulator in combination together with an oscillator that creates the needed optical transporter frequency, observed by an Erbium doped fibre amplifier (EDFA). P2P and point-to-multipoint connections are available on Radio over fiber networks. Using the millimetre-wave spectrum, a full-duplex Radio around fiber system capable of transmitting 2.54 GB/s data over 45 km by fewer than 3 dB power reduction was recently established [6]. Millimetre wave signals can be varied and upconverted using a diversity of cost-effective optical methods. Table 1 Encapsulates and comparisons the significant characteristics of both allowing tools of Fi-Wi networks.

Table 1. Comparisons of the Prominent Features of Both allowing Technologies of Fi-Wi Networks.

Features	RoF	FSO
Connectivity	Point-to-point and point-to-multipoint	Point-to-point
Availability	Maximum in mist minimum in rain	Minimum in mist. Maximum in rain
Transmission mode	Full duplex	Full duplex
Scalability	Less in terms of bandwidth Maximum in terms of customer and facility	Maximum in terms of bandwidth Less in terms of user and service
Interference	Electromagnetic signals	Background sunlight
Spectrum license	Required	Not required

3.1 Recent Works on Fi-Wi Networks

The particulars of the numerous protection mechanisms that have been planned in literature can now be studied, after the protocol environment has been described and the motivations for WDM survival have been discussed. To categorise these strategies, several general and orthogonal criteria can be assumed.

The precise sublayer of the WDM layer in this assumed protection structure functions is the first categorization criterion. Optical multiplex section sublayer and Optical channel sublayer are two options. In the primary scenario, the entity to be protected is the light path, therefore OCh safeguard is also recognized as path safeguard. In the occasion of a collapse, every intermittent light path's protective path is activated [7,8]. The OCh equipment located at the light path's end-nodes (source and destination) inductees' recovery operations. These procedures are also accountable for monitoring light paths and noticing letdowns. The operative light path is the protected entity, while the protective light path is switched over if the optical circuit fails. As stated later, this light channel can be pre-allocated or enthusiastically established. The multiplex of WDM channels conveyed on a fibre is the OMS-sublayer achieved entity, as previously specified. As a consequence, at this sublayer, fault retrieval takes into justification each network link distinctly, which is also known as link protection.

Another significant feature that distinguishes WDM survivable networks is the dynamic management of protective capacity. There are two significantly different approaches to this property [8]. Preplanning is the most common strategy in real-world commercial applications: standby assets are assigned when a light route is recognized (on-line) or, if the traffic is fundamentally static, through network preparation (off-line). The network is "ready22" to respond to a disaster: once a disaster has been revealed, the nodes must undertake basic switching happenings, often without the necessity for network management system involvement. This aspect permits us to recover rapidly; nonetheless, every WDM channel is firmly assigned to function as a functioning or unused resource. At the very minimum, some early prepared practices exist where emergency channels can be cast-off to communicated own significance traffic (pre-emptive) that can be stopped or lost in order to reinstate superior significance traffic in the event of failure. Provisioning (also known as restoration) is a substitute to preplanning [8]. In this situation, the network is planned with a resource distribution that is greater than the actual working-traffic needs, and not at all spare ability is assigned. When a connection fails, the network creates new ones to substitute the broken ones. Allowing delivers the benefit of giving the network approach more plasticity, potentially enhancing resource application for working traffic. Another benefit is that it allows the network to tolerate numerous simultaneous failures (as in the case of a large-scale ecological disaster). A preplanned network, on the other hand, cannot face an undetermined amount of simultaneous failures due to the tight association between protection resources and operational light paths [9] [10].

In 2003, N.J. Frigo et al. reported that Spectral Slicing techniques in the local access network can enable point-to-multipoint, point-to-point and multiple access applications [11]. Including spectrum allocation, it is possible to run numerous independent networks on a single common infrastructure, with service and quality of service segmentation. Non-linear modulation transfer functions cause the majority of component impairments. This disadvantage is connected to the linearity of the modulator /24/ when a wideband basis may be modulated profitably (for dispersed services such as television). Once the service is beyond localized and LEDs are employed as suppliers, on the other hand, thermal /24/ and dynamic carrier /25/ impacts must be taken into account. Spectral sharing has changed from a means for carrying a variety of different assistance types on a WDM infrastructure that uses a WGR to a method for so long as cheap point-to-point links on a traditional WDM PON. This allows for the use of a same physical infrastructure to enable both high-capacity point-to-point circuits and cost-effective delivery of both packet-based switching services and distributive broadcast services on bus architectures.

T. Koonen et al. proposed next-generation optical access in 2008, such as wavelength routing for effortlessly adjustable hosting of facilities, flexible capacity allocation and facility benefactors, and radio-over-fiber procedures that enable centralized radio signal processing, creating a powerful symbiosis of the fibre world and the wireless world [4]. Fiber is now success the access domain after captivating the core and city networks. Its minimal deficit and larger bandwidth facilitate the release of any current or expected set of broadband facilities, as well as making it a decent match for the end user's wireless link. Cost effectiveness is a main consideration that will influence network topology decisions. When it comes to point-to-point short-reach access, may be the most cost-effective, whereas point-to-multipoint may be the most attractive when it comes to medium- to extended-achieve access, or when route closures in the regional conversation become a major concern. A variety of optical procedures on the basis of frequency slot multiplexing, time slot multiplexing, wavelength multiplexing and code division multiplexing are discussed, as well as their use in fibre to the home/fiber to the locations (FTTH/FTTP) networks for profligate information transmission (asynchronous transfer mode (ATM) or Ethernet based) and broadband facility circulation (such as CATV). Techniques aimed at following-creation optical access are being calculated in research laboratories, such as wavelength routing for elastic volume allocation and effortlessly adjustable hosting of facilities and service providers, and radio-over-fiber techniques that enable centralized radio signal processing, making an influential cooperation of the fibre world and the wireless world.

Sunil Kim et al. proposed a protective technique in 2008, in which gridlock ways are pre-planned and employed in the case of a connection breakdown. For many features such as resource use speed of recovery and the use of spare capacity, both defence and restoration systems have advantages and disadvantages [12]. It introduces dynamic protection reconfiguration, which is used to quickly reconfigure recovery pathways and reallocate protective wavelengths following a failure (in real time), allowing for maximum recovery from repeated failures. We consider protection rather than (dynamic) restoration because we focus on recovery strategies that promise less than 100ms recovery time. Multiple failure protection planning is a more capacity-inefficient alternative to dynamic protection reconfiguration, or DPR for short.

The long-term survivability of a WDM passive optical network is investigated by X. Cheng et al. (2008). A novel WDM-PON architecture with self-preservation and in-service fault localization abilities was presented [13]. Here multiple WDM-PONs are coupled, a multiple sub-ring architecture is created. When an optical network unit fails, protective switching takes place automatically (ONUs).Fibre fault localization, Fiber loss and automatic protection switching in each ONU are monitored in actual time in the central office without disrupting client service (CO). For disaster alarm or protection switching, neither CO nor ONUs need signalling. The extra fibres compulsory for protection are condensed when associated to preceding protection methods.

In 2017, Puja et al. provided a solution to the multiple ONU placement challenge in Fi-Wi. In this regard, the efficient Moth Flame Optimization (MFO) population-based approach is proposed [14]. The findings of the simulation were compared to two commonly utilised existing techniques. Optimal ONU placement has a number of benefits, including improved throughput, fewer interference, effective load harmonizing, and price savings. The integration of a wireless access network and an optical network is identified as a Fiber-Wireless (Fi-Wi) or hybrid wireless-optical broadband access network (WOBAN). This multi-domain network combines the aids of wireless and optical domains to meet the wants of customers. Fiber-Wireless has cost-effectiveness, flexibility, resilience, high capacity, and reliability, as well as the potential to self-organize. In Fiber-Wireless (Fi-Wi), the Optical Network Unit (ONU) placement problem streamlines improves performance and network design in terms of cost efficiency and advanced throughput. Numerous individual-based methods have been planned for ONU placement, such Tabu Search, Simulated Annealing (SA) and others, but these algorithms hurt from untimely conjunction (trapping in a local optima). A current study tackles Fi-Wi deployment and presents the Moth-Flame optimization (MFO) algorithm, a revolutionary nature-inspired heuristic paradigm for multiple optical network unit placement. The MFO algorithm is based on the population. Local optima avoidance is better handled by population-based algorithms.

Minesh et al. published a paper in 2018 suggesting a bi-directional planning to reduce RB-RE noise in wavelength recycled bi- directional Radio over Fiber. Upstream and downstream transmission is done using (OFDM) Optical Orthogonal Frequency Division Multiplexing and Single Sideband techniques. If not used in combination with a suitable RB mitigation strategy, the interferometric beat noise caused by passive device reflections (RE) and Rayleigh backscattering (RB) in wavelength reprocess bidirectional fibre optic transmission systems lowers the system [15]. Implementation of modulation methods that decrease the spectral overlap amid the data signal and the RB-RE signals can reduce these disturbances. In this study, a bidirectional architecture for wavelength reprocessed bidirectional Radio over Fiber (RoF) is presented to reduce RB-RE noise. Upstream and downstream transmission is done using Optical Orthogonal Frequency Division Multiplexing and Single Sideband techniques. The MZM uses a hybrid coupler to generate distinct phase shifts (90° and 120°) of the RF signal applied to its electrodes, subsequent in two SSB millimetre wave signals: regular SSB and adapted SSB. By broadcasting the downstream and upstream signals on the advanced and inferior first order optical sidebands of the SSB signal, correspondingly, the spectral overlap between the information signal and the RB-RE signals is decreased in our structure. Based on RB-RE interferences, a scientific model is built to inspect the broadcast performance of the two SSB methods. The two SSB modulation systems are utilized to transport 12GBps data across 70 km fibre utilizing an m-QAM optical OFDM baseband modulation system. In comparison to the conservative SSB, our fallouts show that the improved SSB eliminates 2nd order RB-RE harmonics and lowers RB-RE crosstalk.

In 2019, Puja et al. attempted to enhance the location of many ONUs in a Fi-Wi network. Whale Optimization Algorithm's Efficient Nature [16]. The influence of ONU assignment on deployment cost, network throughput, and survivability in the future. The current study describes the application of a network and proposals the Whale Optimization Algorithm (WOA), a revolutionary population-based metaheuristic paradigm for optimal placement of numerous ONUs based on diverse distributions of wireless routers and ONUs. The outcomes are associated to Greedy and Moth Flame Optimization (MFO) approaches that are presently in use.

Harris Hawks Optimization algorithm (HHO) developed by Puja et al. in 2020. This method has been used to determine the best locations for many ONUs. Since HHO is a population-based gradient-free optimization technique, it can be used to resolve any optimization problem with the right preparation. The surprise pounce [17] cooperative behaviour and chasing style of Harris hawks in nature (desert setting) inspired this optimization technique.

3.2 Architectures

This section depicts the numerous architectures for allowing Fi-Wi integration. There are a variety of ways to merge EPON and WiMAX access networks, for example; affording to [18], the subsequent4 topologies be able to be utilized

Independent Architecture

WiMAX centre stations that serve portable client nodes are connected to an optical network unit (ONU) in the same way that any additional wired contributor node is, with an ONU indicating EPON consumer principles apparatus. EPON and WiMAX networks are associated over a familiar interface (e.g., Ethernet) and operate self-sufficiently.

Hybrid Architecture

In this technique employs an ONU-base station (ONU-BS) that blends EPON ONU hardware and software with WiMAX BS software and hardware. The dynamic bandwidth allotment for the ONU and BS is managed by the integrated ONU-BS.

Unified Connection-Oriented Architecture

In this technique Unified Connection-Oriented Architecture (UCOA) is a type of architecture that focuses on connecting people. This method employs an combined ONU-BS. As a substitute of Ethernet frames, WiMAX MAC procedure information units including many compressed Ethernet frames are utilized. By passing WiMAX MAC PDUs, the unified architecture is able to operate as a WiMAX network, with the option of fine-tuning bandwidth allocation utilizing WiMAX's connection-oriented bandwidth allocation relatively than EPON's queue-oriented bandwidth distribution.

Microwave-over-Fiber Architecture

In this technique modulates the WiMAX wave on a wireless transporter frequency before multiplexing and moderating it through the base-band EPON indicator onto a photosensitive frequency (wavelength) at the ONU-BS. The main node is made up of a regular EPON optical line terminal (OLT) and a central WiMAX BS, also known as a macro-BS. The OLT processes the baseband EPON wave, whereas the macro-BS practices information packets from numerous WiMAX BS units.

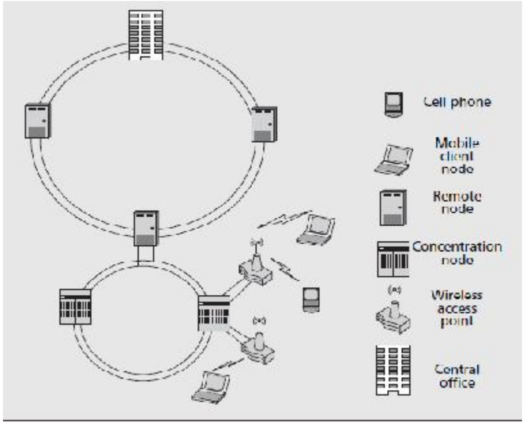

Figure 2: Optical Unified Bidirectional Fiber Rings Combined With Wi-Fi-Based Wireless Access Points.

For opaque WDM (DWDM)/subcarrier multiplexing (SCM) broadband Fi-Wi networks, Figure 2 displays a multi-level dual directional line-secured ring (BPR) topology [19]. The CO uses a dual-fiber ring to connect remote nodes (RNs) in this architecture. Each RN sends WAPs to MCNs via application nodes (CNs), where every WAP provides essential services. The CO is outfitted with double circles of protection mechanisms (usual and standby). Every RN is made up of a safety unit and a multilayer dielectric interference filter-based bidirectional wavelength add-drop multiplexer.

4. CONCLUSION

By flawlessly merger optical and wireless access skills, hybrid Fi-Wi Access Network access networks hold a lot of potential for enabling a large scale of upcoming and evolving broadband facilities and requests on the same infrastructure. Research and advance of upcoming Fi-Wi network plannings and protocols has made important progress, but there are still a number of open issues to be resolved, primarily in the areas of minimum cost component design, combined routing, end-to-end facility differentiation, and resiliency, in order to make Fi-Wi access resolutions commercially feasible, according to this study. Fi-Wi Access Network networks can combine (optical) wired and wireless access networks, which are generally measured distinctly, by concurrently providing wired and wireless services finished the same infrastructure, possibly saving money. A fascinating upcoming research topic would be to compare the economics of numerous Fi-Wi Access Network designs.

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