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Trimet Graph Optimization (TGO) based methodology for Scalability and Survivability in Wireless Networks

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ABSTRACT

Wireless networks gain popularity in recent years with tremendous growth in Wi-Fi, 5G cellular, V2X, Low-power wide-area, Wireless-sensing, Millimeter-wave, Backscatter networks. The common problem we identified in the above technologies is scalability and survivability will affect the performance of the systems. The current development demands for an improvement in traditional topologies. The above challenges cannot be addressed by a star, wheel, full mesh chain, ring, and etc. due to lack of scalability, survivability and resilience properties. These problems can be addressed in different ways by using machine learning, AI, game theory, etc. In this paper graph theory techniques were applied because this method is well equipped with mathematical techniques that provide a systematic alternative to traditional topologies. Physical features like cost, latency, congestion, survivability, resilience are correlated with graph invariants like node degree, diameter, average distance, and edge betweenness and Wiener impact. The above-mentioned Scalability, survivability problems are applied on backhaul, wireless networks respectively. Finally, a general framework was designed for wireless networks using the NetworkX package in python.

Key words: IOT, Scalability, Survivability, TGO, Graph Theory, Graph Invariants, Topology optimization, NetworkX.

1. INTRODUCTION

Since decades the design of wireless networks like WSN, IoT and communication technologies like backhaul, front haul networks have been integrated with problems like cost, performance, survivability, etc. Earlier researchers suggested a common topology that would reduce the design complexity and achieve a general cost optimization, which was later realized wrongs because of missing important properties like scalability, survivability, resilience, etc. In wireless networks, basic topologies like a star, ring, bus, and the mesh were used for various applications which are not fulfilling the needs. We can also design new topologies by combing basic graphs called hybrid topologies. Hybrid topologies as not further categorized. Research has to do in this aspect for a better selection of topology and application. In [1] a special category of hybrid topologies is designed by combing star, trimet and wheel graphs for a wide variety of applications in WSN, IoT and backhaul networks. Graph theory plays an important role in solving many engineering problems. In this paper scalability and survivability, problems were addressed by careful analysis of the Pappus graph, Tutte graph, Peterson graph, Heawood graph, Barbell graph, Mobius-Kantor graph, dodecahedral graph, Desargues graph. Above mentioned graphs will be useful for so extent in solving real-time problems but there is a scope for designing hybrid topologies for specific applications. Network Science is a field of studying complex networks [2]. This science was widely used in the analysis of different wireless, biological, telecommunication, and social networks. By my observation Network science is an incremental process of graph theory because in both the cases basic representation with nodes and edges. In designing new models graph theory can be used, similarly in visualizing data mining and statistics was used. In recent days active research is going on Facebook and biological analysis [3]. A review on graph properties like centrality, degree, betweenness, page rank, clustering, degree distribution, assortativity, distance with the following model's watts–Strogatz, erdős–rényi, barabási–Albert, random regular graphs, barbell graph, dorogovtsev_goltsev_mendes_graph, small world graph [4].

1.1 Common challenges in the design of Backhaul and wireless topologies

- Node Survivability: It is a process of sustained network even after removing N nodes randomly.
- Edge Survivability: It is a process of holding the connection of a network even after removing N edges randomly. In any case, if an edge is lost then node or device will also be lost so edges play an important role in designing networks.
- Scalability: In recent days IoT devices are increased in terms of billions. Interconnecting these devices is a big challenge for network designers. This problem reduces the performance of an overall network.

2. RELATED WORK

In this survey, we focused on mainly three concepts like scalability, backhaul topologies, and survivability. The purpose of this study is to apply the above properties invariant fields in wireless networks. Author [5] talks about leveraging the commodity Ethernet switches to support the aggregate bandwidth of clusters nearly 10,000 elements. The author resolved his topology around the fat-tress and present techniques to perform scalable routing, therefore, they can deliver scalable bandwidth at the minimum cost compared to the existing techniques. In [6] data center networks have been used to meet the requirements of cloud technologies properties like diameter, bandwidth, scaling, and resiliency, survivable and routing. The level tree topology was introducing by combing the basic principles of a tree and complete graphs. The proposed model was compared jellyfish, fat tree, volvoxDC.In [7] dynamic environments were used on robots for various operations. Different agents have to be interconnected in a network for better communication. The author has introduced the archetypal model for distributed systems in this paper are a ring, 2Dmesh, random networks, cavemen topologies are compared [8]. In [9] author presents the SOCRA architecture which makes use of the SDN control panel which is responsible for the entire configuration-related operations. The results show that it is possible to restructure the backhaul without any significant impact on current existing UE traffic. as a part of the feature work, the author intends to investigate the different impacts of the backhaul channel assignment using different positing and distances of the Backhaul nodes and interfaces. A method for designing robust backhaul topologies based on graph invariants by proposing new invariants called the node wiener impact which measures the impact of the node failure in [10]. Apart from this, they are currently working node wieners impact invariant to analyze the impact of link failures. The author shall also work on how the method behaves in a heterogeneous cloud radio access network (H-CRAN). Total power consumption of the AN and BN has been minimized by optimizing the ABJEE performance of both SBSs and the whole systems they referred to the cooperative game theory to establish a golden utility function. An author in [11] has also mentioned about the delay issue they intended to include the queuing process of UE data packets as a part of future work. In [12] details with the survivability issues in post-disaster optical networks, he also proposed a scheme called RSS scheme (reliability-sustainable-survivability) to overcome the effect of the damage caused. The author analyzed the reliability of connection delivered over a signal path or lined disjoined double path. The propose RSS can be achieved in terms of the traffic loss ratio and connection reliability. [13] Focus is on the connectivity and availability of network topology using WSN.After removing a few links between nodes. He introduced a model base CML called the cascading model of WSN and proposed four methods for network topology construction by considering the main features on WS'}N.We attempts to optimized the network to reduce cascading failures in his feature works. In [14] chooses a topological structure which is fault tolerance to design an interconnection network. This topological design of a network achieves a specified performance at minimal cost by assigning link capabilities and links for connecting nodes between the networks. This paper has proposed a design that represents in-depth performance analysis compared to the author existing methods.

3. PROPOSED TGO METHODOLOGY

In the proposed models we have designed topological models by combination star, trimet graphs. TGO model is an optimized model which is having 2 edge survivability and this model can also support scalability property by combing above topologies [15], [16]. In this paper, an indirect way of designing and analysis of two major challenges like scalability and survivability was addressed. This model grounded with graph theoretical optimization which refines the exits networks [17]. In table 1 an indirect way of topological graph invariant characteristics is correlated with general features of wireless networks. This method reduces efforts in designing and analyzing networks. In figure 1 basic design of TGO formation was explained with dominant, hanging and special vertices [18]. Similarly, table 2 gives information about notations used in following proposed algorithms.

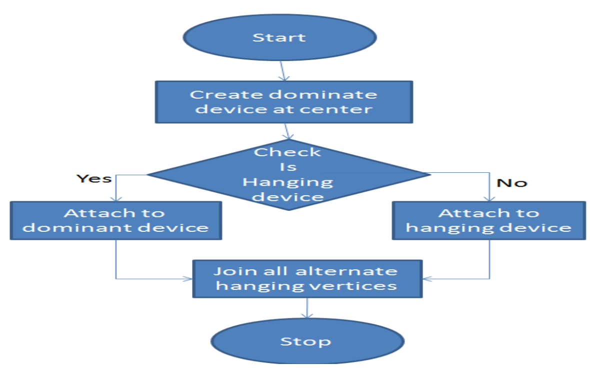


Figure 1: Flow chart for TGO Mesh Formation

Table 1: Network requirements and graph invariants

Feature	Invariant
Cost	Order, size, average degree
Maximum latency	Diameter
Average latency	Average distance
Network Congestion	Edge betweenness and degree variance
Survivability	2-connectivity

Table 2: Notationsused in the proposed algorithms

Symbol	Description
V	Total number of vertices in a network
D_v	Dominant vertices
H_v	Hanging vertices
S_v	Special vertices
V_s	Variable size
F_s	Fixed-size
S_s	star
T_g	Trimet graph
C_n	Cluster

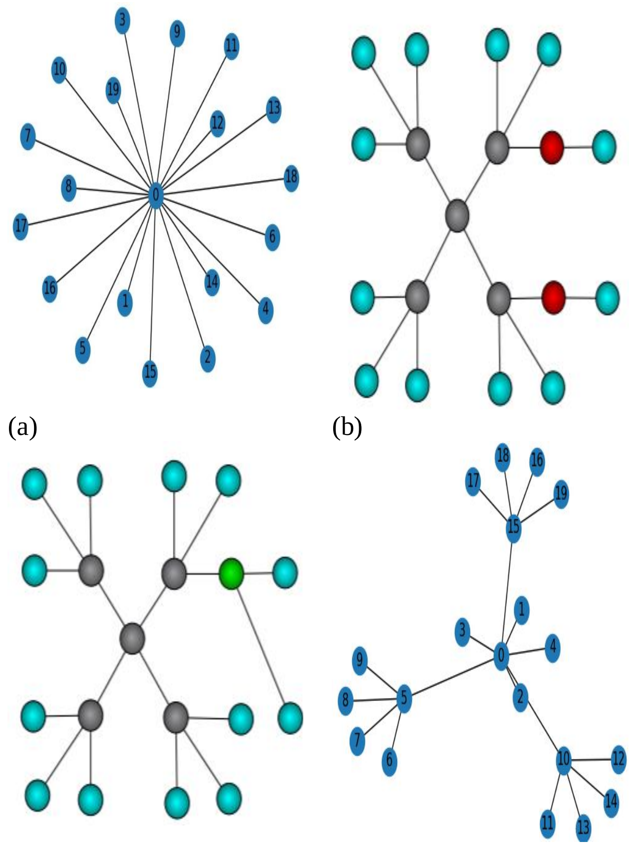
3.1 Scalability in Backhaul Topologies

The telecommunications network was categorized into two types they are backhaul and front haul topologies. In front haul C-RAN (Centralized Radio Access Network) topologies are used, similarly in backhaul star, chain, tree, ring topologies [18]. Scalability places an important role in many engineering designs. In computers, its impact is very high in wireless networks like IoT and Cellular networks. In figure 2 (a) star (b) Expert (c) AGX (d) star of star are displayed. Star of a star, trimet, TGO are new models designed for backhaul topologies. Proposed models are compared with graph parameters like degree, diameter, Average length, etc. In star, a node with maximum degree fails total graph will be disconnected so, in an expert, AGX, star of a star is proposed to overcome high degree problems in a network. In figure 3, figure 4 two edge connected networks like a ring, wheel, AGX, Trimet, Hierarchical Ring, TGO models are displayed [19].

Proposed Algorithm 1

Input: *$V=\{D_v, H_v, S_v\}$, $C_n=\{D_{vn}, H_{vn}, S_{vn}\}$*
Output: *S_s of S_s(Star of Star)*

1. *Start*
2. *Creations of n number of clusters with vertices set V of a network.*
3. *If ($X=V_s$)*
4. *Variable size clusters are formed using Fibonacci sequence.*
5. *Else ($X=F_s$)*
6. *Fixed size clusters are formed with a constant numerical value.*
7. *After formation of clusters.*
8. *Apply Star graph algorithm recursively on each cluster and also on dominant vertices D_{vn}in a network*
9. *Star of Star (S_s of S_s) network is generated.*
10. *Stop*



(a) (b) (c) (d)

Figure 2: Tree based Networks in backhaul (a) star (b) Expert (c) AGX (d) star of star

Table 3: Tree based topologies

Sno	Invariants	Star	Expert	AGX	Star of Star
1	Max Degree	18	4	4	7
2	Average Degree	1.89	1.89	1.89	1.89
3	Diameter	2	6	5	4
4	Average Distance	1.89	3.18	3.16	2.78
5	Wiener index	324	544	540	529
6	Max/Min Edge betweeness	18/18	70/18	78/18	39/9

Proposed Algorithm 2

1. *Start*
2. *Deployment of D_v at the center of a network.*
3. *Attach remaining hanging vertices (H_v) to D_v in a network.*
4. *Star network is generated*
5. *If (V=odd)*
6. *Connect alternate hanging vertices (H_v) with an edges*
7. *Else (V=even)*
8. *Connect alternate hanging vertices (H_v) with an edges and join left over S_v to any sector*
9. *Trimet graph (T_v) network is generated.*
10. *Stop*

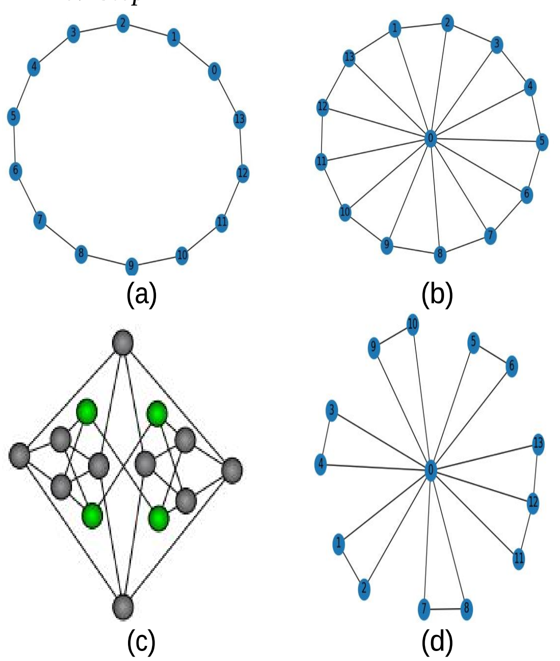


Figure 3: Two Edge connected graphs (a)Ring (b)Wheel (c)AGX (d) Trimet graph

Table 4: 2-Connected based topologies

Sno	Invariants	Ring	Wheel	AGX	Trimet
1	No of Edges	14	26	26	20
2	Max Degree	2	13	4	13
3	Average Degree	2	3.71	3.71	2.85
4	Diameter	7	2	3	2
5	Average Distance	3.77	1.71	2.04	1.78
6	Wiener index	343	156	186	162
7	Max/Min Edge betweeness	24.5/24.5	10/2	12/6.5	13/1

Proposed Algorithm 3

1. *Start*
2. *Creations of n number of clusters with vertices set V of a network.*
3. *If (X=V_s)*
4. *Variable size clusters are formed using Fibonacci sequence.*
5. *Else (X=F_s)*
6. *Fixed size clusters are formed with a constant numerical value.*
7. *After formation of clusters.*
8. *Apply Trimet graph algorithm recursively on each cluster and also on dominant vertices D_{vn} in a network*
9. *Trimet graph of Trimet graph ($_{Tg}$ of $_{Tg}$) network is generated.*
10. *Stop*

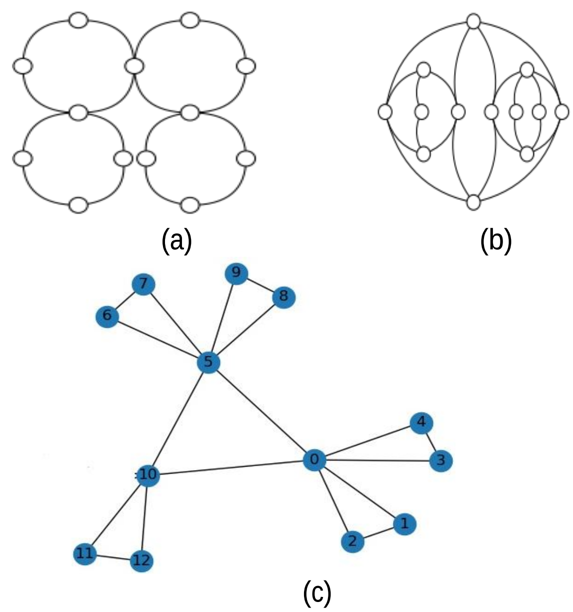


Figure 4: 2-Edge connected networ a) Hierarchical Ring b) AGX c) TGO model

Table 5: CRAN topologies

Sno	Invariants	Hierarchical Ring	AGX	TGO of TGO
1	No of Edges	16	22	18
2	Max Degree	4	4	6
3	Avg Degree	2.46	3.38	2.76
4	Diameter	6	6	3
5	Average Distance	2.72	2.49	2.17
6	Wiener index	212	194	170
7	Max/Min Edge betweeness	33.5/6.5	11/6.25	32/1.2

3.2 Survivability in Wireless networks.

Internet of Things is a concept based on the connection and identification of physical objects among themselves via the internet. When a physical object or device becomes capable of representing itself digitally, it becomes much more valuable than its current self. This makes it possible for the Internet of Things to affect both governmental as well as industrial sectors in a positive way very efficiently [20]. From the last 3 years, the usage of IoT devices are increased drastically due to this a major scalability issue will be raised along with survivability [21], [22]. To address these challenges a novel topology is required. The future with the Internet of Things has the potential to impact how we live and how we work. Scale-free properties are observed in many wireless networks, so in this paper, we are correlating both properties and analysis was performed on graph matrices [23], [24]. Python is a high-level programming language that tends to attract programmers with increased productivity. Python provides high-level built-in data structures which make it useful for rapid application development. Since python is interpreted, the instructions are executed directly and freely in most of its implementations. NetworkX is basically a python package used exclusively for complex networks. It deals with loading and storing networks in different data formats. NetworkX is also meant to be a highly portable framework for the analysis of both networks as well as social networks. Real world graphs actually operate on NetworkX. Since NetworkX is free software, it can be redistributed and modified upon having licenses [25]. In this paper, a framework has been designed on proposed networks like the star of start, Trimet, TGO, and other models by using NetworkX. The proposed tool was designed for multiple benefits. Trimet or not, trimet graph, TGO scalable, TGO survivable models are main design goals in this research other modules like a general graph, general scalable, application modules can be used by other researchers. In compare module graphical represent of results can be analyzed by bar charts.

Proposed Algorithm 4

Input: *$V=\{D_v, H_v, S_v\}$, $C_n=\{D_{vn}, H_{vn}, S_{vn}\}$*
Output: *T_g of T_g(TGO of TGO)*

1. *Start*
2. *Creations of n number of clusters with vertices set V of a network.*
3. *Unequal Size clusters are formed using Fibonacci sequence.*
4. *Apply Trimet graph algorithm recursively on each cluster and also on dominant vertices Dvn in a network*
5. *Trimet graph of Trimet graph (Tg of Tg) network is generated.*
6. *Removing of Nodes randomly in an iterative process.*
7. *stop*

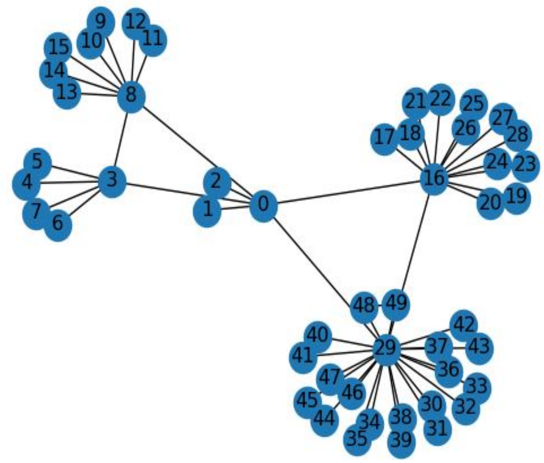


Figure 5: Diagrammatic representation of proposed Fibonacci based clustering

4. RESULTS AND DISCUSSION

In the above tables, comparisons were done with standard network science parameters like degree, diameter, average distance, wiener index, and edge betweenness. In this paper a new model star of star, trimet, TGO was compared with a star, expert, AGX models. In table 3 proposed star of star, the model has a moderate max degree because it lies in between the star and expert systems. Average degree is common for all models because of a similar network structure. It has less diameter, low average distance, small wiener index, optimal edge betweenness than expert and AGX models but these parameters are slightly higher than a star. In table 4 proposed trimet has optimal results over the AGX model. In table 5 proposed TGO of TGO have better results over the AGX model except for max degree and max edge betweenness.

In this section node survivability was addressed by removing nodes randomly in each iteration until the network was disconnected. Implementation of the above algorithm was done with python programming by using NetworkX package. TGO model was compared with low clustering, medium clustering, high clustering and Fibonacci clustering. It is observed that Fibonacci clustering is more survivable because until 210 nodes was removed network network is connected. Until removal of 91, 36, 10 nodes nodes from medium, high and low clusters respectively and clearly shows that Fibonacci clustering was formed with minimum edges with initial (1484) and final states (1089). In figure 6 average clustering of Fibonacci network was observed high at initial state (0.988) and low (0.77) at final state.average path length and transitivity of Fibonacci network is low in initial and final states.

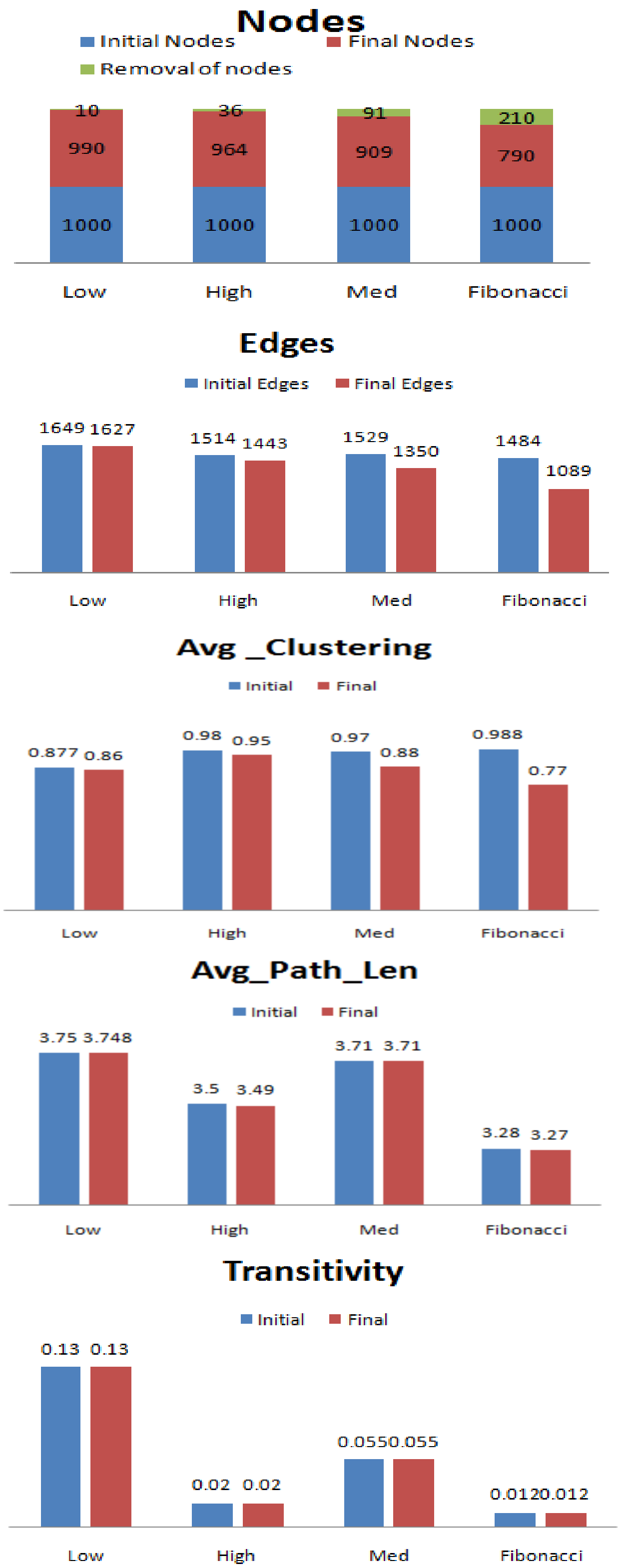


Figure 6: Comparison of low, high, medium clustering with Fibonacci clustering.

5. CONCLUSION

In recent days abundant use of electronic devices leads to common issues like scalability and survivability are found in wireless technologies. In this paper, optimal scalable backhaul networks and Survivable Wireless network was designed. In backhaul networks, three algorithms are proposed with variable design goals. Star of a star, Trimet, TGO models are analyzed with standard networks like a ring, AGX, expert, Hierarchical Ring, and wheel. Proposed models are generating better results than AGX model. Survivability is a mechanism to withstanding networks even after the removal of nodes in random. In Survivability model TGO was comparing with low, medium, high clustering networks with Fibonacci based clustering. Proposed model is showing better performance than low, medium and high clustering. A python-based general framework was designed using NetworkX, math plot lib, PyQt5, and NumPy packages. The proposed framework was designed not only to analyze TGO models but general models are also implemented for the research community. In this framework type and size of the network has to be selected then he can visualize and get the basic in-formation about the model. For better analysis on the graph, properties compare module is designed and it can generate bar charts for visualization.

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