Data Article

Big datasets of optical-wireless cyber-physical systems for optimizing manufacturing services in the internet of things-enabled industry 4.0

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ARTICLE INFO

Article history:
Received 6 December 2021
Revised 1 March 2022
Accepted 2 March 2022
Available online 9 March 2022

Dataset link: Big Dataset of Optical-Wireless Cyber-Physical Systems for Optimizing Manufacturing Services in the Internet of Things-enabled Industry 4.0 (Original data)

Keywords:
Internet of things
Big data
Optical sensor network
Wireless sensor network
Industry 4.0

ABSTRACT

The Industry 4.0 revolution is aimed to optimize the product design according to the customers’ demand, quality requirements and economic feasibility. Industry 4.0 employs advanced two-way communication technologies for optimizing the manufacturing process to increase the sales of the products and revenues to cope the existing global economy issues. In Industry 4.0, big data obtained from the Internet of Things (IoT)-enabled industrial Cyber-Physical Systems (CPS) plays an important role in enhancing the system service performance to boost the productivity with enhanced quality of customer experience. This paper presents the big datasets obtained from the Internet of things (IoT)-enabled Optical-Wireless Sensor Networks (OWSNs) for optimizing service systems’ performance in the electronics manufacturing Industry 4.0. The updated raw and analyzed big datasets of our published work [3] contain five values namely, data delivery, latency, congestion, throughput, and packet error rate in OWSNs. The obtained dataset are useful for optimizing the service system performance in the electronics manufacturing Industry 4.0.

https://doi.org/10.1016/j.dib.2022.108026
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Specifications Table

| Subject                                      | Computer Science: Computer Networks and Communications |
|----------------------------------------------|--------------------------------------------------------|
| Specific subject area                       | Optical-wireless communication in the electronics manufacturing Industry 4.0. |
| Type of data                                 | Graphs and Tables                                      |
| How the data were acquired                   | Data was captured using Internet of things-enabled optical-wireless sensor networks in the electronics manufacturing Industry 4.0. |
| Data format                                  | Raw and analyzed optical-wireless sensors data in an electronics manufacturing Industry 4.0. |
| Description of data collection               | The big data sets were collected by optical-wireless sensor networks deployed on different types of manufacturing and assembly systems in the electronics Industry 4.0. To collect the big data in a particular scenario, a static topology by taking into account the line-of-sight and the non-line-of-sight issues was considered in an indoor industrial environment. To gather real-time big data from the systems involved in the electronics manufacturing process a cobot, i.e., the static sink was deployed in a specific location in the plant. The remote user can access and configure both wireless and optical nodes by connecting to the cobot through the intranet or the internet communication technologies such as the 5G. Distinct from the existing sink, the cobot can intelligently monitor, learn and configure the entire deployed network by closely monitoring the human interventions. Thus, the cobot minimizes the user interventions in the whole big data gathering process in Industry 4.0. |
| Parameters for data collection               | The data was gathered in day and night by employing wireless and optical sensors numbering 450 and 100, respectively. The wireless sensor nodes are equipped with physical layer standard IEEE 802.15.4 and frequency 2.4 GHz unlicensed industrial, scientific and medical (ISM) band. The optical nodes are equipped with physical layer standard IEEE 802.15.7 using light wavelengths from 7000 nm to 300 nm (LED technology), which varies based on the applications. In addition, the group leader nodes are equipped with both physical layer standards IEEE 802.15.4 and IEEE 802.15.7 for wireless and optical communication in the network. City/Town/Region: Kayseri/Kocasinan, Country: Turkey, Latitude and longitude (and GPS coordinates, if possible) for collected samples/data: N38 °71′ and E35 °43′. |
| Data source location                         | Data repository name: Mendeley |
|                                              | Data identification number: DOI: 10.17632/8kdvdbhrxt.3 |
|                                              | Direct URL t o data: [https://data.mendeley.com/datasets/8kdvdbhrxt/3](https://data.mendeley.com/datasets/8kdvdbhrxt/3) |
| Related research paper                       | M. Faheem, R. A. Butt, R. Ali, B. Raza, M. A. Ngadi, and V. C. Gungor, “CBI4. 0: A Cross-layer Approach for Big Data Gathering for Active Monitoring and Maintenance in the Manufacturing Industry 4.0,” *Journal of Industrial Information Integration*, p. 100236, 2021. [https://doi.org/10.1016/j.jii.2021.100236](https://doi.org/10.1016/j.jii.2021.100236) |

Value of the Data

- The data presented in the article provides a fundamental building block of the next-generation Internet of things-enabled optical-wireless communication architectures for big data gathering in the electronics manufacturing Industry 4.0.
- The published data will guide scientists for low-cost and energy efficient integration of different types of cyber-physical systems with varying data capacity requirements, and operate them optimally within realistic network scenarios in the electronics manufacturing Industry 4.0.
- The data presented in the article will serve as a guide for readers for closely monitoring the assembly and manufacturing processes in real-time to minimize the faulty products and to boost the production process with lesser human interventions in the electronics manufacturing Industry 4.0.
• The published data can be used as a benchmark problem by researchers interested in artificial intelligence-based network analysis of different types of manufacturing systems in the manufacturing Industry 4.0.

1. Data Description

Internet of things is an emerging domain that promises ubiquitous connection of various devices to the Internet in several industrial applications like e-health, manufacturing, logistics, and utilities [1–3]. However, the accuracy of obtaining the big data from the IoT-enabled OWSNs is very challenging due to moving objects, obstacles, line-of-sight, and non-line-of-sight issues in an electronics manufacturing Industry 4.0 [4–8]. The offered dataset in this article provides essential information for real-time observations of the electronics manufacturing process in an electronics manufacturing Industry 4.0. The offered datasets guide the researchers about how to identify the faulty systems placed in various positions. Thus, it allows the system monitoring and control personnel to take appropriate actions for improving the quality and quantity of the product to meet customer demands. The data offered in this article were collected using wireless and optical sensors placed in different positions on different electronics manufacturing and assembly systems in an indoor industrial environment. In the deployed network, each node is responsible to observe the surroundings and collaborates with the neighboring node to forward the sensed information to the cobot. Unlike the traditional sink, the cobot is an intelligent device that can learn from human actions and perform actions on demand. Therefore, the deployed optical-sensor network requires less human intervention in the monitoring and control processes.

Fig. 1 describes the network model deployed in Industry 4.0. In Fig. 1, the colored circle shape icons indicate the different types of sensor nodes, e.g., proximity sensor, level sensor,

![Fig. 1. A view of the network model in an electronics manufacturing Industry 4.0 [3].](image-url)
motion sensor, position sensor, etc. In particular, the red-colored circle icon is equipped with both wireless and optical line of sight characteristics compared to the rest of sensors, which only can communicate wirelessly in the network. The dotted circle shows the communication range of a sensor node embedded in the manufacturing systems for fault monitoring purposes. The blue-colored box icons show optical sensors equipped with multiple LED in different lines of directions. The solid arrows and light black color dotted lines show the wireless and optical communication, respectively. The computer-like icon is a cobot (sink), which is equipped with optical sensors to communicate with the rest of the deployed network. The cloud-like icon indicates the Internet with different types of networks. Consequently, the cobot is equipped with 5G communication technology to communicate with the Internet. Consequently, a remote user using Internet of Services (IoS) and IoT such as 5G bi-directional communication links can interact with the deployed network to directly configure, monitor, control, and configure the network.

Table 1 describes the datasets related to the ratio of data delivery in OWSNs. It clearly shows that the data delivery ratio (DDR) of OWRP in the initial rounds between 1 and 1000 is high around 99.95% compared to 93.15% in CARP. However, the DDR value of OWRP is decreasing from 99.15%, 99.81%, 99.83%, 99.59 %, and to 99.25% when the round numbers are between 2000 and 5000 in the network. However, the datasets show that the value of DDR is decreasing rapidly from 93.14%, 93.46%, 92.73%, 93.06%, and to 91.68% in CARP compared to the OWRP scheme in the network. On the other hand, the DDR value of DCFBR is reducing up to 90.93%, 88.83%, 87.26%, 85.50%, 85.69%, and 84.60% between round numbers 100 and 1000, 1001 and 2000, 2001 and 3000, 3001 and 4000, 4001 and 5000, and 5001 and 5500, respectively, in the network. The average of obtained PDR big datasets graphically is shown in Fig. 2.

Table 2 describes the latency to the latency in the OWSNs. The obtained big datasets illustrate that the latency value (LV) of OWRP with node density between 1 and 100 is low around 30ms compared to 63ms in CARP. However, the latency value of OWRP is increasing around 48ms, 66ms, 85ms, 117ms, and 131ms when the numbers optical-wireless sensor nodes are between 110 and 550 in the network. The datasets show that the LV is increasing rapidly around 63ms, 98ms, 170ms, 235ms, 291ms, and 350ms in CARP compared to the OWRP scheme in the network. On the other hand, the LV of DCFBR is noticed around 62ms, 89ms, 137ms, 186, 267ms, 308ms with number of nodes between 10 and 100, 101 and 200, 201 and 300, 301 and 400, 401 and 500, and 501 and 550, respectively, in the network. The average of obtained LV big datasets graphically is shown in Fig. 3.

Table 3 shows the datasets related to congestion management in the OWSNs. The obtained big datasets illustrate that the congestion management value (CM) of OWRP with node density between 1 and 100 is high around 99.8% compared to 98.8% in CARP. However, the CM value of OWRP is decreasing around 99.5%, 98.6%, 98.7%, 97.4 %, and 97.1% when the numbers optical-wireless sensor nodes are between 110 and 550 in the network. On the other hand, the datasets show that the CM is decreasing rapidly around 96.2%, 91.2%, 87.5%, 86%, and 85.6% in CARP compared to the OWRP scheme in the network. On the other hand, the CM value of DCFBR is recorded around 98.3%, 95.6%, 92%, 86%, 82.3%, and 81.3% with nodes density between 1 and 550 in the network. The average of obtained CM big datasets graphically is shown in Fig. 4.

Table 4 shows the datasets related to throughput in the OWSNs. The obtained big datasets show that the throughput value (TP) of OWRP with node density between 1 and 100 is high around 99.2% compared to 91.2% in CARP. However, the TP value of OWRP is changing around 99.1%, 98.9%, 98.95%, 98.84 %, and 99.04% when the numbers optical-wireless sensor nodes are between 110 and 550 in the network. The big datasets show that the TP is decreasing rapidly around 91.4%, 90.3%, 90.3% and rising up to 91.7%, and 91.8% in the same round numbers in CARP compared to the OWRP scheme in the network. On the other hand, the TP value in DCFBR is noticed low around 87.8%, 87.5%, 87.4%, 87.4%, 87.1%, and 87.5% between round numbers 100 and 1000, 1001 and 2000, 2001 and 3000, 3001 and 4000, 4001 and 5000, and 5001 and 5500, respectively. The average of obtained TP big datasets graphically is shown in Fig. 5.

Table 5 shows the datasets related to packet error rate in the OWSNs. The obtained big datasets show that the packet error rate value (PER) of OWRP with node density between 1 and 100 is low around 0.2% compared to 0.35% in CARP and 0.39% in DCFBR. The PER value
Table 1
Datasets for packet delivery ratio in OWSNs.

| No. of rounds | Protocols | OWRP | Avg. \( \equiv \) (%) | CARP | Avg. \( \equiv \) (%) | DCFBR | Avg. \( \equiv \) (%) |
|---------------|-----------|------|------------------------|------|------------------------|-------|------------------------|
| 100           |           | 0.009995 |              | 0.009315 |              | 0.009208 |              |
| 200           |           | 0.009989 |              | 0.009387 |              | 0.009276 |              |
| 300           |           | 0.009989 |              | 0.009344 |              | 0.009295 |              |
| 400           |           | 0.009988 |              | 0.009369 |              | 0.009168 |              |
| 500           |           | 0.009966 | 0.009978   | 0.009361 | 0.009361   | 0.009068 | 0.009093   |
| 600           |           | 0.009990 |              | 0.009282 |              | 0.009077 |              |
| 700           |           | 0.009959 |              | 0.009477 |              | 0.009133 |              |
| 800           |           | 0.009997 |              | 0.009206 |              | 0.009074 |              |
| 900           |           | 0.009959 |              | 0.009397 |              | 0.008906 |              |
| 1000          |           | 0.009948 |              | 0.009472 |              | 0.008903 |              |
| 1100          |           | 0.009969 |              | 0.008968 |              | 0.008916 |              |
| 1200          |           | 0.009987 |              | 0.009096 |              | 0.008955 |              |
| 1300          |           | 0.009992 |              | 0.009292 |              | 0.008915 |              |
| 1400          |           | 0.009950 |              | 0.009248 |              | 0.008994 |              |
| 1500          |           | 0.009880 | 0.009962   | 0.009429 | 0.009315   | 0.008849 | 0.008883   |
| 1600          |           | 0.009998 |              | 0.009365 |              | 0.008878 |              |
| 1700          |           | 0.009973 |              | 0.009467 |              | 0.008837 |              |
| 1800          |           | 0.009997 |              | 0.009191 |              | 0.008893 |              |
| 1900          |           | 0.009978 |              | 0.009570 |              | 0.008776 |              |
| 2000          |           | 0.009987 |              | 0.009519 |              | 0.008776 |              |
| 2100          |           | 0.009988 |              | 0.009490 |              | 0.008741 |              |
| 2200          |           | 0.009991 |              | 0.009247 |              | 0.008774 |              |
| 2300          |           | 0.009993 |              | 0.009389 |              | 0.008779 |              |
| 2400          |           | 0.009993 |              | 0.009358 |              | 0.008797 |              |
| 2500          |           | 0.009983 | 0.009981   | 0.009334 | 0.009346   | 0.008696 | 0.008726   |
| 2600          |           | 0.009998 |              | 0.009487 |              | 0.008781 |              |
| 2700          |           | 0.009997 |              | 0.009406 |              | 0.008702 |              |
| 2800          |           | 0.009981 |              | 0.009310 |              | 0.008697 |              |
| 2900          |           | 0.009981 |              | 0.009115 |              | 0.008616 |              |
| 3000          |           | 0.009995 |              | 0.009325 |              | 0.008674 |              |
| 3100          |           | 0.009989 |              | 0.009372 |              | 0.008679 |              |
| 3200          |           | 0.009989 |              | 0.009399 |              | 0.008699 |              |
| 3300          |           | 0.009979 |              | 0.009299 |              | 0.008694 |              |
| 3400          |           | 0.009987 |              | 0.008979 |              | 0.008685 |              |
| 3500          |           | 0.009988 | 0.009983   | 0.009561 | 0.009273   | 0.008646 | 0.008650   |
| 3600          |           | 0.009983 |              | 0.009490 |              | 0.008699 |              |
| 3700          |           | 0.009986 |              | 0.009151 |              | 0.008559 |              |
| 3800          |           | 0.009978 |              | 0.009349 |              | 0.008548 |              |
| 3900          |           | 0.009977 |              | 0.008918 |              | 0.008614 |              |
| 4000          |           | 0.009975 |              | 0.009218 |              | 0.008679 |              |
| 4100          |           | 0.009995 |              | 0.009378 |              | 0.008679 |              |
| 4200          |           | 0.009946 |              | 0.009495 |              | 0.008659 |              |
| 4300          |           | 0.009988 |              | 0.009334 |              | 0.008554 |              |
| 4400          |           | 0.009989 |              | 0.009283 |              | 0.008582 |              |
| 4500          |           | 0.009978 | 0.009959   | 0.009290 | 0.009306   | 0.008550 | 0.008569   |
| 4600          |           | 0.009916 |              | 0.008912 |              | 0.008552 |              |
| 4700          |           | 0.009962 |              | 0.009398 |              | 0.008592 |              |
| 4800          |           | 0.009957 |              | 0.009268 |              | 0.008537 |              |
| 4900          |           | 0.009942 |              | 0.009314 |              | 0.008515 |              |
| 5000          |           | 0.009921 |              | 0.009397 |              | 0.008464 |              |
| 5100          |           | 0.009955 |              | 0.009203 |              | 0.008493 |              |
| 5200          |           | 0.009912 |              | 0.009282 |              | 0.008472 |              |
| 5300          |           | 0.009933 | 0.009925   | 0.009091 | 0.009168   | 0.008470 | 0.008460   |
| 5400          |           | 0.009901 |              | 0.009335 |              | 0.008433 |              |
| 5500          |           | 0.009925 |              | 0.008930 |              | 0.008430 |              |
of OWRP is changing around 0.33%, 0.38%, 0.46%, 0.59%, and 0.73% when the numbers optical-wireless sensor nodes are between 110 and 550 in the network. Similarly, the PER value of CARP is changing around 0.46%, 0.63%, 1.1%, 1.65%, and 2.3% when the numbers optical-wireless sensor nodes are between 110 and 550 in the network. Compared to all other schemes, the PER value of DCFBR is observed high around 0.61%, 0.98%, 1.5%, 2.63%, and 3.37% between 110 and 550 against the OWRP and CARP in the network. The average of obtained PER big datasets graphically is shown in Fig. 6.
| No. of nodes | OWRP  | CARP  | DCFFB | Avg. ≅ (ms) |
|------------|-------|-------|-------|-------------|
| 10         | 0.001588 | 0.003957 | 0.003950 |
| 20         | 0.001818 | 0.004988 | 0.004875 |
| 30         | 0.002239 | 0.005737 | 0.005633 |
| 40         | 0.002545 | 0.006152 | 0.006055 |
| 50         | 0.002741 | 0.006512 | 0.006310 | 0.006160 |
| 60         | 0.003209 | 0.006783 | 0.006585 |
| 70         | 0.003483 | 0.007119 | 0.006911 |
| 80         | 0.003767 | 0.007390 | 0.007050 |
| 90         | 0.004072 | 0.007408 | 0.007098 |
| 100        | 0.004084 | 0.007519 | 0.007211 |
| 110        | 0.004289 | 0.007680 | 0.007320 |
| 120        | 0.004356 | 0.008290 | 0.008001 |
| 130        | 0.004467 | 0.008850 | 0.008222 |
| 140        | 0.004483 | 0.009190 | 0.008560 |
| 150        | 0.004593 | 0.009530 0.009844 | 0.008840 | 0.008942 |
| 160        | 0.004677 | 0.009910 | 0.009315 |
| 170        | 0.004868 | 0.010190 | 0.009695 |
| 180        | 0.005099 | 0.011020 | 0.009723 |
| 190        | 0.005378 | 0.011770 | 0.009772 |
| 200        | 0.005489 | 0.012010 | 0.009964 |
| 210        | 0.005541 | 0.012991 | 0.010888 |
| 220        | 0.005688 | 0.014122 | 0.010278 |
| 230        | 0.005954 | 0.015711 | 0.012556 |
| 240        | 0.006373 | 0.016802 | 0.012915 |
| 250        | 0.006555 | 0.016582 | 0.016984 | 0.013147 | 0.013673 |
| 260        | 0.006792 | 0.017934 | 0.014155 |
| 270        | 0.006879 | 0.018381 | 0.015394 |
| 280        | 0.007169 | 0.018593 | 0.015587 |
| 290        | 0.007378 | 0.018788 | 0.015872 |
| 300        | 0.007489 | 0.018842 | 0.015941 |
| 310        | 0.007546 | 0.018990 | 0.015800 |
| 320        | 0.007758 | 0.019820 | 0.016327 |
| 330        | 0.008169 | 0.020719 | 0.016729 |
| 340        | 0.008273 | 0.021508 | 0.016908 |
| 350        | 0.008451 | 0.008544 | 0.023077 | 0.023486 | 0.017071 | 0.018627 |
| 360        | 0.008672 | 0.025137 | 0.018188 |
| 370        | 0.008778 | 0.026085 | 0.019088 |
| 380        | 0.009135 | 0.026393 | 0.020399 |
| 390        | 0.009266 | 0.026588 | 0.022522 |
| 400        | 0.009393 | 0.026547 | 0.023240 |
| 410        | 0.01197 | 0.026689 | 0.023890 |
| 420        | 0.011389 | 0.027488 | 0.024422 |
| 430        | 0.011592 | 0.028076 | 0.025079 |
| 440        | 0.010777 | 0.028558 | 0.025889 |
| 450        | 0.010911 | 0.011703 | 0.028975 | 0.029048 | 0.026972 | 0.026696 |
| 460        | 0.011975 | 0.029483 | 0.026480 |
| 470        | 0.012078 | 0.029689 | 0.027688 |
| 480        | 0.012138 | 0.029798 | 0.027703 |
| 490        | 0.012389 | 0.029968 | 0.028900 |
| 500        | 0.012584 | 0.031549 | 0.029940 |
| 510        | 0.012611 | 0.032011 | 0.030011 |
| 520        | 0.012757 | 0.033922 | 0.030901 |
| 530        | 0.013135 | 0.035510 | 0.035049 | 0.030980 | 0.030782 |
| 540        | 0.013313 | 0.036301 | 0.031001 |
| 550        | 0.013501 | 0.037501 | 0.031015 |
Fig. 3. Effect of node density to network delay
Table 3
Datasets for congestion management in OWSNs.

| No. of nodes | Protocols | OWRP Avg. \( \equiv \% \) | CARP Avg. \( \equiv \% \) | DCFBR Avg. \( \equiv \% \) |
|--------------|-----------|--------------------------|--------------------------|--------------------------|
| 10           | 0.009999  | 0.009999                  | 0.009901                  |
| 20           | 0.009999  | 0.009970                  | 0.009900                  |
| 30           | 0.009998  | 0.009961                  | 0.009903                  |
| 40           | 0.009997  | 0.009852                  | 0.009800                  |
| 50           | 0.009897  | 0.009850                  | 0.009840 0.009834        |
| 60           | 0.009895  | 0.009840                  | 0.009833                  |
| 70           | 0.009993  | 0.009833                  | 0.009832                  |
| 80           | 0.009990  | 0.009830                  | 0.009812                  |
| 90           | 0.009989  | 0.009820                  | 0.009805                  |
| 100          | 0.009989  | 0.009815 0.009709         |
| 110          | 0.009986  | 0.009780                  | 0.009700                  |
| 120          | 0.009979  | 0.009755                  | 0.009702                  |
| 130          | 0.009978  | 0.009701                  | 0.009661                  |
| 140          | 0.009973  | 0.009670                  | 0.009630                  |
| 150          | 0.009872  | 0.009653 0.009617 0.009560 |
| 160          | 0.009865  | 0.009620                  | 0.009570                  |
| 170          | 0.009959  | 0.009569                  | 0.009529                  |
| 180          | 0.009955  | 0.009546                  | 0.009500                  |
| 190          | 0.009949  | 0.009470                  | 0.009401                  |
| 200          | 0.009948  | 0.009405 0.009304         |
| 210          | 0.009941  | 0.009360                  | 0.009302                  |
| 220          | 0.009915  | 0.009305                  | 0.009301                  |
| 230          | 0.009880  | 0.009260                  | 0.009290                  |
| 240          | 0.009865  | 0.009210                  | 0.009280                  |
| 250          | 0.009848  | 0.009203 0.009115 0.009194 |
| 260          | 0.009848  | 0.009101                  | 0.009251                  |
| 270          | 0.009843  | 0.009000                  | 0.009190                  |
| 280          | 0.009841  | 0.008947                  | 0.009021                  |
| 290          | 0.009841  | 0.008915                  | 0.009082                  |
| 300          | 0.009841  | 0.008850 0.008955         |
| 310          | 0.009830  | 0.008844                  | 0.008944                  |
| 320          | 0.009915  | 0.008820                  | 0.008828                  |
| 330          | 0.009812  | 0.008812                  | 0.008755                  |
| 340          | 0.009807  | 0.008801                  | 0.008700                  |
| 350          | 0.009803  | 0.008770 0.008750 0.008590 |
| 360          | 0.009801  | 0.008755                  | 0.008511                  |
| 370          | 0.009795  | 0.008709                  | 0.008480                  |
| 380          | 0.009791  | 0.008677                  | 0.008380                  |
| 390          | 0.009791  | 0.008656                  | 0.008366                  |
| 400          | 0.009790  | 0.008651 0.008301         |
| 410          | 0.009760  | 0.008644                  | 0.008300                  |
| 420          | 0.009751  | 0.008630                  | 0.008288                  |
| 430          | 0.009744  | 0.008623                  | 0.008253                  |
| 440          | 0.009743  | 0.008611                  | 0.008251                  |
| 450          | 0.009743  | 0.009741 0.008601 0.008605 0.008241 0.008225 |
| 460          | 0.009741  | 0.008600                  | 0.008200                  |
| 470          | 0.009738  | 0.008589                  | 0.008199                  |
| 480          | 0.009733  | 0.008587                  | 0.008187                  |
| 490          | 0.009730  | 0.008581                  | 0.008181                  |
| 500          | 0.009730  | 0.008581 0.008150         |
| 510          | 0.009728  | 0.008570                  | 0.008140                  |
| 520          | 0.009722  | 0.008566                  | 0.008136                  |
| 530          | 0.009719  | 0.009719 0.008549 0.008555 0.008129 0.008129 |
| 540          | 0.009718  | 0.008545                  | 0.008125                  |
| 550          | 0.009710  | 0.008544                  | 0.008114                  |
Fig. 4. Effect of nodes density on congestion management
### Table 4
Datasets for throughput in OWSNs.

| No. of rounds | Throughput values | Protocols |
|---------------|-------------------|-----------|
|               | OWRP              | CARP      | DCFBR    | Avg. ≈ (%) | Avg. ≈ (%) | Avg. ≈ (%) |
| 100           | 0.009891          | 0.009189  | 0.008790 |             |             |             |
| 200           | 0.009875          | 0.009174  | 0.008787 |             |             |             |
| 300           | 0.009888          | 0.009166  | 0.008771 |             |             |             |
| 400           | 0.009871          | 0.009157  | 0.008772 |             |             |             |
| 500           | 0.009899          | 0.009150  | 0.008760 | 0.009184   | 0.008768   |             |
| 600           | 0.009885          | 0.009148  | 0.008772 |             |             |             |
| 700           | 0.009990          | 0.009137  | 0.008760 |             |             |             |
| 800           | 0.009992          | 0.009133  | 0.008762 |             |             |             |
| 900           | 0.009991          | 0.009128  | 0.008750 |             |             |             |
| **1000**      | **0.009900**      | **0.009119** | **0.008754**   |             |             |             |
| 1100          | 0.009901          | 0.009165  | 0.008760 |             |             |             |
| 1200          | 0.009989          | 0.009146  | 0.008765 |             |             |             |
| 1300          | 0.009968          | 0.009161  | 0.008722 |             |             |             |
| 1400          | 0.009966          | 0.009150  | 0.008745 |             |             |             |
| 1500          | 0.009889          | 0.009140  | 0.008767 | 0.009188   | 0.008753   |             |
| 1600          | 0.009874          | 0.009158  | 0.008787 |             |             |             |
| 1700          | 0.009879          | 0.009137  | 0.008734 |             |             |             |
| 1800          | 0.009801          | 0.009116  | 0.008789 |             |             |             |
| 1900          | 0.009911          | 0.009120  | 0.008712 |             |             |             |
| **2000**      | **0.009898**      | **0.009112** | **0.008745**   |             |             |             |
| 2100          | 0.009846          | 0.009062  | 0.008761 |             |             |             |
| 2200          | 0.009867          | 0.009035  | 0.008734 |             |             |             |
| 2300          | 0.009887          | 0.009014  | 0.008734 |             |             |             |
| 2400          | 0.009895          | 0.009036  | 0.008745 |             |             |             |
| 2500          | 0.009888          | 0.009103  | 0.008765 | 0.009188   | 0.008742   |             |
| 2600          | 0.009998          | 0.009011  | 0.008777 |             |             |             |
| 2700          | 0.009848          | 0.009002  | 0.008701 |             |             |             |
| 2800          | 0.009878          | 0.009018  | 0.008741 |             |             |             |
| 2900          | 0.009876          | 0.009019  | 0.008711 |             |             |             |
| **3000**      | **0.009889**      | **0.009050** | **0.008753**   |             |             |             |
| 3100          | 0.009870          | 0.009045  | 0.008722 |             |             |             |
| 3200          | 0.009910          | 0.009022  | 0.008724 |             |             |             |
| 3300          | 0.009911          | 0.009012  | 0.008756 |             |             |             |
| 3400          | 0.009924          | 0.009023  | 0.008767 |             |             |             |
| 3500          | 0.009803          | 0.009045  | 0.008776 | 0.009188   | 0.008744   |             |
| 3600          | 0.009889          | 0.009005  | 0.008737 |             |             |             |
| 3700          | 0.009899          | 0.009069  | 0.008723 |             |             |             |
| 3800          | 0.009891          | 0.009022  | 0.008727 |             |             |             |
| 3900          | 0.009931          | 0.009056  | 0.008754 |             |             |             |
| **4000**      | **0.009920**      | **0.009031** | **0.008754**   |             |             |             |
| 4100          | 0.009869          | 0.009181  | 0.008702 |             |             |             |
| 4200          | 0.009855          | 0.009156  | 0.008711 |             |             |             |
| 4300          | 0.009876          | 0.009111  | 0.008722 |             |             |             |
| 44000         | 0.009940          | 0.009180  | 0.008710 |             |             |             |
| 4500          | 0.009801          | 0.009165  | 0.008701 | 0.009188   | 0.008712   |             |
| 4600          | 0.009841          | 0.009178  | 0.008702 |             |             |             |
| 4700          | 0.009901          | 0.009145  | 0.008701 |             |             |             |
| 4800          | 0.009977          | 0.009189  | 0.008711 |             |             |             |
| 4900          | 0.009887          | 0.009187  | 0.008743 |             |             |             |
| **5000**      | **0.009888**      | **0.009188** | **0.008715**   |             |             |             |
| 5100          | 0.009878          | 0.009178  | 0.008765 |             |             |             |
| 5200          | 0.009920          | 0.009186  | 0.008737 |             |             |             |
| 5300          | 0.009911          | 0.009197  | 0.008726 | 0.009179   | 0.008750   |             |
| 5400          | 0.00990          | 0.009165  | 0.008743 |             |             |             |
| **5500**      | **0.009911**      | **0.009170** | **0.008781**   |             |             |             |
Fig. 5. Effect of number of rounds to throughput
Table 5
Datasets for packet error rate in OWSNs.

| No. of nodes | Protocols | Packet error rate values |
|--------------|-----------|--------------------------|
|              | OWRP      | Avg. ≈ (%) | CARP     | Avg. ≈ (%) | DCFBR   | Avg. ≈ (%) |
| 10           | 0.001100  | 0.001498   | 0.001992 |           |         |           |
| 20           | 0.001200  | 0.002588   | 0.003383 |           |         |           |
| 30           | 0.001350  | 0.003694   | 0.003966 |           |         |           |
| 40           | 0.001600  | 0.003789   | 0.004089 |           |         |           |
| 50           | 0.001700  | 0.003894   | 0.003538 | 0.004124  | 0.003893|           |
| 60           | 0.001900  | 0.003881   | 0.004255 |           |         |           |
| 70           | 0.002100  | 0.003987   | 0.004275 |           |         |           |
| 80           | 0.002600  | 0.003977   | 0.004289 |           |         |           |
| 90           | 0.003110  | 0.003981   | 0.004276 |           |         |           |
| 100          | 0.003200  | 0.004091   | 0.004283 |           |         |           |
| 110          | 0.003208  | 0.004223   | 0.004356 |           |         |           |
| 120          | 0.003251  | 0.004243   | 0.004754 |           |         |           |
| 130          | 0.003285  | 0.004345   | 0.005187 |           |         |           |
| 140          | 0.003291  | 0.004456   | 0.005579 |           |         |           |
| 150          | 0.003301  | 0.004534   | 0.006155 | 0.006145  |         |           |
| 160          | 0.003310  | 0.00459    | 0.006584 |           |         |           |
| 170          | 0.003312  | 0.004765   | 0.006745 |           |         |           |
| 180          | 0.003330  | 0.004878   | 0.006911 |           |         |           |
| 190          | 0.003380  | 0.004989   | 0.007391 |           |         |           |
| 200          | 0.003393  | 0.005012   | 0.007789 |           |         |           |
| 210          | 0.003458  | 0.005176   | 0.007886 |           |         |           |
| 220          | 0.003531  | 0.005287   | 0.008179 |           |         |           |
| 230          | 0.003616  | 0.005574   | 0.008278 |           |         |           |
| 240          | 0.003688  | 0.005867   | 0.008510 |           |         |           |
| 250          | 0.003756  | 0.006278   | 0.008983 | 0.009757  |         |           |
| 260          | 0.003790  | 0.006549   | 0.009491 |           |         |           |
| 270          | 0.003852  | 0.006769   | 0.008782 |           |         |           |
| 280          | 0.003859  | 0.006922   | 0.009979 |           |         |           |
| 290          | 0.003970  | 0.007323   | 0.012710 |           |         |           |
| 300          | 0.004127  | 0.007711   | 0.014768 |           |         |           |
| 310          | 0.004278  | 0.008067   | 0.015468 |           |         |           |
| 320          | 0.004331  | 0.008567   | 0.015124 |           |         |           |
| 330          | 0.004366  | 0.009078   | 0.015663 |           |         |           |
| 340          | 0.004488  | 0.009387   | 0.015967 |           |         |           |
| 350          | 0.004536  | 0.009789   | 0.0010923| 0.016276  | 0.015060|           |
| 360          | 0.004620  | 0.011265   | 0.016837 |           |         |           |
| 370          | 0.004752  | 0.011456   | 0.017223 |           |         |           |
| 380          | 0.004887  | 0.012487   | 0.017627 |           |         |           |
| 390          | 0.004946  | 0.013543   | 0.017954 |           |         |           |
| 400          | 0.005089  | 0.015634   | 0.018454 |           |         |           |
| 410          | 0.005182  | 0.01543    | 0.021479 |           |         |           |
| 420          | 0.005275  | 0.018327   | 0.022686 |           |         |           |
| 430          | 0.005388  | 0.012430   | 0.023588 |           |         |           |
| 440          | 0.005566  | 0.013511   | 0.024990 |           |         |           |
| 450          | 0.005725  | 0.005886   | 0.015600 | 0.016519  | 0.025691| 0.026294|
| 460          | 0.005908  | 0.017201   | 0.026685 |           |         |           |
| 470          | 0.006160  | 0.018456   | 0.027790 |           |         |           |
| 480          | 0.006367  | 0.019409   | 0.028703 |           |         |           |
| 490          | 0.006518  | 0.022510   | 0.029711 |           |         |           |
| 500          | 0.006767  | 0.022601   | 0.030612 |           |         |           |
| 510          | 0.006845  | 0.022704   | 0.031619 |           |         |           |
| 520          | 0.007056  | 0.022802   | 0.032830 |           |         |           |
| 530          | 0.007376  | 0.007311   | 0.023311 | 0.023172  | 0.033528| 0.033742|
| 540          | 0.007587  | 0.023751   | 0.034845 |           |         |           |
| 550          | 0.007689  | 0.023291   | 0.035887 |           |         |           |
2. Experimental Design, Materials and Methods

In this work, a set of optical and wireless sensor nodes were statically embedded in different systems located in an area of 285 (length) × 110 (width) in the indoor electronics manufacturing industrial environment. The number of optical sensor nodes, compliant to IEEE 802.15.7 physical layer standard and operating on the wavelength from 7000nm to 300nm are set to 100. On the other hand, the wireless sensor nodes, compliant to physical layer standard IEEE 802.15.4 are set to 450. In the deployment, the nodes equipped with both wireless and optical communication technologies act like gateway head nodes and are responsible for gathering observed data from neighboring nodes and forward it to the cobot via optical communication technology. The energy of each wireless node is set to 15J with a communication range of up to 3 to 5m and data rates up to 256 kbps [9]. While the communication range of the optical sensors was set to 10m and data rates up to 1 Gbps. The data packet size of the wireless sensor nodes is set to 72 bytes and uses the Quadrature phase-shift keying (QPSK) modulation mechanism in the network [10]. The memory size of wireless and optical sensor nodes was set to 5Mb and 10Mb, respectively. In addition, the channel and energy consumption model used in this study is the same as discussed in [3,11]. The widely used parameters and values used in existing studies are given in Table 6.
Table 6
Simulation parameters and values

| Simulation Model Parameters                  | Values                                      |
|---------------------------------------------|---------------------------------------------|
| Simulation tool                             | EstiNet 12 & MongoDB                        |
| Cobot (sink)                                | 1                                           |
| Wireless sensors                            | 450                                         |
| Optical sensors                             | 100                                         |
| Physical layer wireless standard            | 802.15.4                                    |
| Physical layer optical standard             | 802.15.7                                    |
| Wavelength for optical standard             | 7000nm to 300nm                             |
| Initial sensor node energy                  | 15J                                         |
| High transmission power                     | 0.46W                                       |
| Low transmission power                      | 0.31W                                       |
| Packet receiving power                      | 0.05W                                       |
| Idle listening                              | 0.023W                                      |
| Sleeping power                              | $3 \times 10^{-6}$W                         |
| Data aggregation                            | 0.019W                                      |
| Packet length                               | 72 bytes                                    |
| Wireless data transfer rate                 | 256 kbps                                    |
| Optical data transfer rate                  | 1Gbps                                       |
| Wireless & optical node cache size          | 5Mb, 10Mb                                   |
| Maximum hop distance wireless sensor        | 3-5m                                        |
| Maximum hop distance optical sensor         | 10m                                         |
| Maximum communication range of the cobot    | 50m                                         |
| Topology                                    | Static                                      |
| Wireless Antenna                            | Omni-directional                            |
| LED (Optical)                               | Line-of-sight                               |
| Path loss exponent for the LoS and non-LoS | 1.4, 1.9                                    |
| The noise floor for the LoS and non-LoS     | -89, -97                                    |
| Shadowing deviation for the LoS and non-LoS | 1.12, 1.92                                  |
| Area: 2D (length × width)                   | $285 \times 110m$                           |
| Simulation time                             | 300 sec                                     |
| Set of simulations                          | 60                                          |

Ethics Statement

We declare that the manuscript adheres to Ethics in publishing standards and the submitted dataset is the real data recorded in the experiment, and there is no act of stealing other people’s data or modifying data.

CRediT Author Statement

Muhammad Faheem: Conceptualization, Methodology, Software, Simulation, Formal analysis, Writing – Original Draft, Project administration; Rizwan Aslam Butt: Methodology, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
Data Availability

Big Dataset of Optical-Wireless Cyber-Physical Systems for Optimizing Manufacturing Services in the Internet of Things-enabled Industry 4.0 (Original data) (Mendeley Data)

Acknowledgments

This research is funded by the Abdullah Gül University, Kayseri, Turkey.

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