Data Article

Big Data acquired by Internet of Things-enabled industrial multichannel wireless sensors networks for active monitoring and control in the smart grid Industry 4.0

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\textbf{A B S T R A C T}

Smart Grid Industry 4.0 (SGI4.0) defines a new paradigm to provide high-quality electricity at a low cost by reacting quickly and effectively to changing energy demands in the highly volatile global markets. However, in SGI4.0, the reliable and efficient gathering and transmission of the observed information from the Internet of Things (IoT)-enabled Cyber-physical systems, such as sensors located in remote places to the control center is the biggest challenge for the Industrial Multichannel Wireless Sensors Networks (IMWSNs). This is due to the harsh nature of the smart grid environment that causes high noise, signal fading, multipath effects, heat, and electromagnetic interference, which reduces the transmission quality and trigger errors in the IMWSNs. Thus, an efficient monitoring and real-time control of unexpected...

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changes in the power generation and distribution processes is essential to guarantee the quality of service (QoS) requirements in the smart grid. In this context, this paper describes the dataset contains measurements acquired by the IMWSNs during events monitoring and control in the smart grid. This work provides an updated detail comparison of our proposed work, including channel detection, channel assignment, and packets forwarding algorithms, collectively called CARP [1] with existing G-RPL [2] and EQSHC [3] schemes in the smart grid. The experimental outcomes show that the dataset and is useful for the design, development, testing, and validation of algorithms for real-time events monitoring and control applications in the smart grid.

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Specifications Table

| Subject                  | Computer Networks and Communication, Engineering. |
|--------------------------|--------------------------------------------------|
| Specific subject area    | MWSNs communication in the smart grid            |
| Type of data             | Tables and Graphs                                 |
| How data were acquired   | Data was captured using sensors in the 500kV outdoor power grid station |
| Data format              | Raw and analysed sensor data in the smart grid    |
| Description of data collection | The data were gathered using sensors in the smart grid environment containing various systems or subsystems and electric poles with values 160 and 120, respectively. In order to gather data in different scenarios, random topologies were considered within the smart grid environment. In the meanwhile, a static sink was deployed near the sensors to collect real-time data in the smart grid. The remote user can access and configure each sensor by connecting to the sink and the base station using wired or wireless intranet and internet communication technologies. |
| Parameters for data collection | The data were collected during the day using 300 sensors, each of them equipped with physical layer standard 802.11g, the frequency range between 2.412GHz and 2.484GHz with random topology in the power grid. |
| Data source location     | City/Town/Region: Kayseri, Country: Turkey.        |
| Related research article | The updated data is related to the research article presented in [1]. |
| Data accessibility       | Data is provided within this article and, Data Repository name: Mendeley |
| Direct URL to data       | https://dx.doi.org/10.17632/32d6r6r6zk.1            |

Value of the Data

- The data provided in this paper provides can be used for efficient monitoring and control of the power generation and distribution processes in the smart grid.
- The data provided in this paper can be used for the integration of distributed power generation sources into the power transmission and distribution systems within realistic network scenarios.
- It can also support reliable and dynamic data capacity requirements of different types of advanced cyber-physical systems equipped with sensors and devices to operate them optimally, either manual or automatic controls, and provide information about their operations to the utilities.
• In case of faults, the designed scheme intelligently monitoring and identifies the faulty systems located in a remote position and notifies the user in real-time, so that appropriate actions can be taken to supply steady electricity to the customers.

1. Data Description

The dataset provided in this paper offers valuable information for efficient monitoring and control of the power generation and distribution processes in the smart grid. The advantage of these data is to provide intelligently monitoring and identifies the faulty systems located in the remote positions to notify the user in real-time so that appropriate actions can be taken to supply steady electricity to the customers. The data provided in this article were gathered using multichannel wireless sensor nodes located at remote locations in an outdoor power generation and distribution centers in the smart grid. In the smart grid, each node by following an event-driven or query-based information gathering model monitors the surrounding, collaborates with each other, and reports the sensed data to the sink. The user using IoT via IoT can directly monitor, control, and configure any deployed sensor node through the base station and the sink as shown in Fig. 1 [1].

In Fig. 1, the black colored icons are the wireless sensor nodes. The unique number on the right side of each sensor node shows the identity in the network. The device equipped with dual antennas on the right side of the deployed network is the sink while the pole like icon is the BS. The orange-colored thick multiple lines generate the same inference level, such as systems, subsystems, and electric poles in the SG. The thin orange-colored lines on the left and right sides defined the network boundary. The blue-colored circular line shows the sink range for message transmission and reception in the network. The black line between the sink and the base station and the base station to the user shows the highly stable bi-directional communication links in the network. The cloud-like icon indicates the network is either a LAN, NAN, or WAN.

Table 1 and Table 2 present the data of the probability of channel detection and the probability of false alarms in the MWSNs. Fig. 2 portrays the trends of both probabilities of channel detection and false alarms in the MWSNs. Table 3 describes the data values of the probability
**Table 1**
The probability of channel detection values in MWSNs.

| No. of rounds | CARP Avg. (≈) | G-RPL Avg. (≈) | EQSHC Avg. (≈) | Protocols |
|---------------|---------------|----------------|-----------------|-----------|
| 100           | 0.9250        | 0.8550         | 0.7880          | CARP      |
| 200           | 0.9280        | 0.8680         | 0.7780          | G-RPL     |
| 300           | 0.9190        | 0.8300         | 0.7630          | EQSHC     |
| 400           | 0.9300        | 0.8390         | 0.7570          | Avg. (≈)  |
| 500           | 0.9190        | 0.8220         | 0.7480          |           |
| 600           | 0.9180        | 0.8310         | 0.7290          |           |
| 700           | 0.9240        | 0.8610         | 0.7250          |           |
| 800           | 0.9320        | 0.8990         | 0.7610          |           |
| 900           | 0.9350        | 0.8400         | 0.7390          |           |
| 1000          | 0.9330        | 0.8580         | 0.7470          |           |
| 1100          | 0.9290        | 0.8590         | 0.7710          |           |
| 1200          | 0.9190        | 0.8300         | 0.7390          |           |
| 1300          | 0.9390        | 0.8290         | 0.7710          |           |
| 1400          | 0.9190        | 0.8320         | 0.7480          |           |
| 1500          | 0.9180        | 0.8510 93.6%   | 0.7290           |
| 1600          | 0.9240        | 0.8610         | 0.7250          |           |
| 1700          | 0.9290        | 0.8490         | 0.7610          |           |
| 1800          | 0.9390        | 0.8500         | 0.7790          |           |
| 1900          | 0.9310        | 0.8480         | 0.7770          |           |
| 2000          | 0.9320        | 0.8690         | 0.7810          |           |
| 2100          | 0.9300        | 0.8300         | 0.7690          |           |
| 2200          | 0.9310        | 0.8490         | 0.7810          |           |
| 2300          | 0.9300        | 0.8500         | 0.7590          |           |
| 2400          | 0.9280        | 0.8580         | 0.7470          |           |
| 2500          | 0.9220        | 0.8720         | 0.7590          |           |
| 2600          | 0.9290        | 0.8790         | 0.7510          |           |
| 2700          | 0.9390        | 0.8600         | 0.7390          |           |
| 2800          | 0.9280        | 0.8580         | 0.7470          |           |
| 2900          | 0.9280        | 0.8680         | 0.7470          |           |
| 3000          | 0.9320        | 0.8420         | 0.7590          |           |

(continued on next page)

**Table 2**
The probability of missed-detection values in MWSNs.

| No. of rounds | CARP Avg. (≈) | G-RPL Avg. (≈) | EQSHC Avg. (≈) | Protocols |
|---------------|---------------|----------------|----------------|-----------|
| 100           | 0.3380        | 0.5280         | 0.9050         | CARP      |
| 200           | 0.3290        | 0.5210         | 0.9040         | G-RPL     |
| 300           | 0.3340        | 0.5180         | 0.9240         | EQSHC     |
| 400           | 0.3990        | 0.5600         | 0.9110         | Avg. (≈)  |
| 500           | 0.3160        | 0.5710         | 0.9020         |           |
| 600           | 0.3150        | 0.5350         | 0.9080         |           |
| 700           | 0.3250        | 0.5800         | 0.8950         |           |
| 800           | 0.3340        | 0.5780         | 0.8970         |           |
| 900           | 3.2980        | 0.5670         | 0.9000         |           |
| 1000          | 0.3980        | 0.5600         | 0.9100         |           |
| 1100          | 0.3040        | 0.5480         | 0.9170         |           |
| 1200          | 0.3290        | 0.5670         | 0.9090         |           |
| 1300          | 0.3040        | 0.5480         | 0.9190         |           |
| 1400          | 0.3160        | 0.5490         | 0.9180         |           |
| 1500          | 0.2990 3.3%   | 0.5550 5.5%    | 0.9180 9%      |           |
| 1600          | 0.3280        | 0.5400         | 0.9080         |           |
| 1700          | 0.3440        | 0.5380         | 0.9000         |           |
| 1800          | 0.3190        | 0.5570         | 0.9110         |           |
| 1900          | 0.3110        | 0.5500         | 0.8910         |           |
| 2000          | 0.3240        | 0.5380         | 0.8990         |           |

(continued on next page)
Table 2 (continued)

| No. of rounds | CARP Avg. (≈) | G-RPL Avg. (≈) | EQSHC Avg. (≈) |
|---------------|--------------|----------------|----------------|
| 2100          | 0.3290       | 0.5470         | 0.9050         |
| 2200          | 0.3340       | 0.5380         | 0.9090         |
| 2300          | 0.3390       | 0.5670         | 0.9950         |
| 2400          | 0.3280       | 0.5400         | 0.8900         |
| 2500          | 0.3290       | 0.5300         | 0.9000         |
| 2600          | 0.3340       | 0.5680         | 0.9090         |
| 2700          | 0.3390       | 0.5620         | 0.8970         |
| 2800          | 0.3380       | 0.5600         | 0.9020         |
| 2900          | 0.3310       | 0.5500         | 0.9100         |
| 3000          | 0.3300       | 0.5530         | 0.9140         |

Fig. 2. The probability of false alarms and probability of detection.

Fig. 3. The probability of missed-detection and probability of detection.
Table 3
The probability of false alarm values in MWSNs.

| No. of rounds | Protocols | CARP Avg. (≈) | G-RPL Avg. (≈) | EQSHC Avg. (≈) |
|---------------|-----------|---------------|----------------|----------------|
| 100           | 0.3110    | 0.9710        | 0.1470          |
| 200           | 0.2370    | 0.8610        | 0.1530          |
| 300           | 0.3360    | 0.8580        | 0.1670          |
| 400           | 0.3420    | 0.9930        | 0.1530          |
| 500           | 0.3350    | 0.8510        | 0.1770          |
| 600           | 0.3380    | 0.9430        | 0.1270          |
| 700           | 0.2430    | 0.8480        | 0.1380          |
| 800           | 0.2460    | 0.8890        | 0.1490          |
| 900           | 0.3390    | 0.9930        | 0.1850          |
| 1000          | 0.2370    | 0.8710        | 0.1540          |
| 1100          | 0.3460    | 0.7890        | 0.1470          |
| 1200          | 0.2390    | 0.7950        | 0.1350          |
| 1300          | 0.3460    | 0.8810        | 0.1490          |
| 1400          | 0.3350    | 0.7510        | 0.1610          |
| 1500          | 0.3380    | 0.8460        | 0.1760          | 15%            |
| 1600          | 0.2430    | 0.8480        | 0.1420          |
| 1700          | 0.3460    | 0.9860        | 0.1490          |
| 1800          | 0.2390    | 0.8910        | 0.1350          |
| 1900          | 0.3370    | 0.9740        | 0.1530          |
| 2000          | 0.3460    | 0.7890        | 0.1490          |
| 2100          | 0.3390    | 0.8950        | 0.1350          |
| 2200          | 0.3460    | 0.7850        | 0.1480          |
| 2300          | 0.3390    | 0.8950        | 0.1350          |
| 2400          | 0.2370    | 0.9740        | 0.1540          |
| 2500          | 0.3400    | 0.9690        | 0.1440          |
| 2600          | 0.3460    | 0.8830        | 0.1490          |
| 2700          | 0.3390    | 0.8950        | 0.1350          |
| 2800          | 0.3370    | 0.9740        | 0.1540          |
| 2900          | 0.2370    | 0.9740        | 0.1530          |
| 3000          | 0.2400    | 0.8610        | 0.8400          |

Fig. 4. The packet delivery ratio vs number of rounds between 1 and 3000.
of missed-detection in the MWSNs. Fig. 3 presents the trends of the probability of channel detection and the probability of missed-detection in the MWSNs. Table 4 describes the packet delivery ratio data values while the graph in Fig. 4 presents the trends of packet delivery ratio in the MWSNs. Table 5 describes the latency data values in the MWSNs. Fig. 5 presents the trends of latency in the MWSNs. Table 6 describes the packet error rate data values while the graph in Fig. 6 shows the trends of the packet error rate in the MWSNs. Finally, Table 7 shows the congestion management data values and Fig. 7 presents the trends of congestion management values in the MWSNs.

2. Experimental Design, Materials and Methods

In this study, we consider a 550 kV outdoor grid station with an area of 1100 (length) × 700 (width) meters containing 300 wireless sensors in the network. The grid contains power generation and distribution systems and subsystem, and electric poles with numbers 160 and 120, respectively. The initial energy of each wireless sensor is set to 5J in the MWSNs. In the MWSNs, each wireless sensor is embedded with physical layer standard IEEE 802.11g with a maximum communication range up to 85 m and data rates up to 256kbps. The IEEE 802.11g standard offers a total number of 12 channels in the 2.4GHz band, in which three, 1, 6, 11, are non-overlapping channels.

Consequently, each sensor is embedded with multiple radios and a single interface, where each radio at a given time serves as a receiver or a transmitter for the distinct channel, i.e., half-
Table 5
The latency values in MWSNs.

| No. of nodes | CARP Avg. (\(\sim\)) | G-RPL Avg. (\(\sim\)) | EQSHC Avg. (\(\sim\)) |
|--------------|-----------------------|------------------------|-----------------------|
| 10           | 0.3000                | 0.3200                 | 0.4900                |
| 20           | 0.4500                | 0.6800                 | 0.5400                |
| 30           | 0.5700                | 0.8800                 | 0.7100                |
| 40           | 0.6400                | 0.1400                 | 0.8000                |
| 50           | 0.7500  77.5%         | 0.1600  201.8%         | 0.9900  140.7%        |
| 60           | 0.8700                | 0.1970                 | 0.1120                |
| 70           | 0.9500                | 0.2560                 | 0.1390                |
| 80           | 0.9900                | 0.2630                 | 0.1050                |
| 90           | 1.0800                | 0.2890                 | 0.1910                |
| 100          | 1.1500                | 0.3010                 | 0.2100                |
| 110          | 0.1400                | 0.3180                 | 0.2270                |
| 120          | 0.1800                | 0.3290                 | 0.2410                |
| 130          | 0.1980                | 0.3450                 | 0.2720                |
| 140          | 0.2100                | 0.3590                 | 0.2980                |
| 150          | 0.2200  226.7%        | 0.3730  418.20%        | 0.3200  379.54%       |
| 160          | 0.2230                | 0.3810                 | 0.3350                |
| 170          | 0.2260                | 0.4390                 | 0.3490                |
| 180          | 0.2600                | 0.4620                 | 0.3680                |
| 190          | 0.2900                | 0.4770                 | 0.3810                |
| 200          | 0.3200                | 0.4910                 | 0.3870                |
| 210          | 0.3240                | 0.4990                 | 0.3990                |
| 220          | 0.3300                | 0.5420                 | 0.4200                |
| 230          | 0.3410                | 0.5710                 | 0.4620                |
| 240          | 0.3640                | 0.5800                 | 0.4750                |
| 250          | 0.3800  398.7%        | 0.6077  543.6%         | 0.4990  479.32%       |
| 260          | 0.3970                | 0.6130                 | 0.5340                |
| 270          | 0.4370                | 0.6380                 | 0.5470                |
| 280          | 0.4630                | 0.6690                 | 0.5630                |
| 290          | 0.4710                | 0.6888                 | 0.5820                |
| 300          | 0.4800                | 0.6940                 | 0.5980                |

Fig. 5. The network delay vs number of sensor nodes between 1 and 300.
Table 6
The packet error rate values in MWSNs.

| No. of nodes | CARP Avg. (≈) | G-RPL Avg. (≈) | EQSHC Avg. (≈) |
|--------------|---------------|----------------|----------------|
| 10           | 0.0100        | 0.0500         | 0.0490         |
| 20           | 0.0900        | 0.4250         | 0.2480         |
| 30           | 0.1800        | 0.3180         | 0.0680         |
| 40           | 0.1600        | 0.5100         | 0.0470         |
| 50           | 0.0600        | 0.3890         | 0.0670         | 1.8% |
| 60           | 0.1200        | 0.3870         | 0.2890         |
| 70           | 0.1500        | 0.3860         | 0.1990         |
| 80           | 0.1300        | 0.3850         | 0.3850         |
| 90           | 0.0940        | 0.4990         | 0.3710         |
| 100          | 0.0530        | 0.5300         | 0.0780         |
| 110          | 0.2280        | 0.6080         | 0.3470         |
| 120          | 0.2150        | 0.7690         | 0.3510         |
| 130          | 0.2170        | 0.8800         | 0.4220         |
| 140          | 0.1700        | 0.9020         | 0.5080         |
| 150          | 0.1850        | 0.9310         | 0.6890         | 6.8% |
| 160          | 0.1600        | 0.9810         | 0.7990         |
| 170          | 0.1800        | 1.2900         | 0.8710         |
| 180          | 0.1700        | 0.9020         | 0.9400         |
| 190          | 0.1800        | 0.9310         | 0.9290         |
| 200          | 0.1900        | 1.1810         | 0.8980         |
| 210          | 0.2790        | 0.8999         | 0.5910         |
| 220          | 0.2590        | 0.9380         | 0.8700         |
| 230          | 0.3310        | 1.3030         | 0.8820         |
| 240          | 0.3440        | 1.3270         | 0.9750         |
| 250          | 0.1660        | 1.3180         | 0.9710         | 9.3% |
| 260          | 0.2990        | 1.2991         | 0.7990         |
| 270          | 0.2870        | 1.3180         | 1.2170         |
| 280          | 0.2590        | 1.2990         | 1.1110         |
| 290          | 0.2790        | 1.4370         | 0.9830         |
| 300          | 0.2850        | 1.4390         | 0.9920         |

Fig. 6. The packet error rate vs number of nodes between 1 and 300.
### Table 7
The congestion management values in MWSNs.

| No. of nodes | CARP Avg. (≈) | G-RPL Avg. (≈) | EQSHC Avg. (≈) |
|--------------|---------------|----------------|---------------|
| 10           | 0.9950        | 0.9700         | 0.9900        |
| 20           | 0.9940        | 0.9650         | 0.9870        |
| 30           | 0.9910        | 0.9560         | 0.9850        |
| 40           | 0.9900        | 0.9480         | 0.9810        |
| 50           | 0.9850 98.07% | 0.9450 94.45% | 0.9780 97.06% |
| 60           | 0.9830        | 0.9430         | 0.9750        |
| 70           | 0.9770        | 0.9350         | 0.9630        |
| 80           | 0.9700        | 0.9300         | 0.9600        |
| 90           | 0.9660        | 0.9290         | 0.9560        |
| 100          | 0.9560        | 0.9240         | 0.9310        |
| 110          | 0.9510        | 0.9200         | 0.9180        |
| 120          | 0.9460        | 0.9160         | 0.9060        |
| 130          | 0.9300        | 0.9090         | 0.8970        |
| 140          | 0.9300        | 0.8940         | 0.8850        |
| 150          | 0.9250 93.02% | 0.8900 89.25% | 0.8800 87.99% |
| 160          | 0.9240        | 0.8860         | 0.8780        |
| 170          | 0.9260        | 0.8820         | 0.8760        |
| 180          | 0.9240        | 0.8800         | 0.8650        |
| 190          | 0.9220        | 0.8750         | 0.8530        |
| 200          | 0.9240        | 0.8730         | 0.8410        |
| 210          | 0.9230        | 0.8710         | 0.8360        |
| 220          | 0.9230        | 0.8720         | 0.8250        |
| 230          | 0.9230        | 0.8700         | 0.8200        |
| 240          | 0.9210        | 0.8660         | 0.8190        |
| 250          | 0.9230 92.20% | 0.8560 84.59% | 0.8110 81.66% |
| 260          | 0.9240        | 0.8490         | 0.8030        |
| 270          | 0.9220        | 0.8300         | 0.7990        |
| 280          | 0.9210        | 0.8260         | 0.7880        |
| 290          | 0.9200        | 0.8190         | 0.8850        |
| 300          | 0.9202        | 0.8000         | 0.7800        |

![Fig. 7](image_url) Fig. 7. The congestion management vs node density between 1 and 300.
duplex mode. The number of available channels on each sensor is equal to the number of radios in MWSNs. Each sensor is equipped with a control channel as a default channel that is always in the receiving mode and can transmit control messages to its neighbors on-demand in a specific deployed area in the network. The Quadrature phase-shift keying (QPSK) modulation technique was assumed and the value of data packet size was set to 43 bytes in the network [3-5]. During the network operations, each wireless sensor observes the grid events and stores data in its memory of the maximum size of 2Mb. In the packet transmission process, the maximum value of energy consumed for transmitting with high and low power was set to 0.97W and 0.82W, while the energy consumed upon receiving data is set to 0.05W in the network.

The values of ideal listening and sleeping power were set to 0.023 W and $3 \times 10^{-6} W$, respectively. Finally, 53 sets of simulations were performed to provide consistent results of the proposed scheme against the existing schemes in the network. The widely used simulation parameters and their values used in our study are given in Table 8 [6-10].

### Table 8
Simulation parameters and values.

| Simulation Model Parameters                                      | Values            |
|------------------------------------------------------------------|-------------------|
| Wireless sensors                                                 | 300               |
| Physical layer standard                                          | 802.11g           |
| Frequency                                                        | 2.412GHz to 2.484GHz |
| Number of channels                                               | 12                |
| Non-overlapping channels                                         | 1,6,11            |
| Initial sensor node energy                                       | 5J                |
| High transmission power                                          | 0.97W             |
| Low transmission power                                           | 0.82W             |
| Packet receiving power                                           | 0.05W             |
| Ideal listening                                                  | 0.023W            |
| Sleeping power                                                   | $3 \times 10^{-6}W$ |
| Data aggregation                                                 | 0.019W            |
| Packet length                                                    | 43 bytes          |
| Data transfer rate                                               | 256 kbps          |
| Cache                                                            | 2Mb               |
| Maximum hop distance                                             | 85m               |
| Maximum communication range of the sink                          | 150m              |
| Topology                                                         | Random            |
| Antenna                                                          | Omni-directional  |
| Path loss exponent for the line of sight and non-line-of-sight   | 2.4, 3.5          |
| The noise floor for the line of sight and non-line-of-sight      | $-83, -91$        |
| Shadowing deviation for the line of sight and non-line-of-sight   | 3.12, 2.92        |
| Systems, subsystems, and poles in the grid                      | 160, 120          |
| Area: 2D (length $\times$ width)                                | $1100 \times 700m$|
| Simulation time                                                  | 120 sec           |
| Set of simulations                                               | 53                |

**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.

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