NEON and SolidRed I-IoT White Paper

Sensor Fusion

For Industry White Paper

Advancing Industrial Operations through Sensor Fusion Technology with NEON TimeSync

1. Introduction

1.1 Overview of I-IoT in the Energy Industry

The Industrial Internet of Things (I-IoT) is revolutionizing the energy industry, transitioning it from traditional methods to advanced, data-driven operations. This white paper focuses on the pivotal role of sensor fusion technology, enhanced by Time Synchronization over the LoRaWAN network, in driving operational excellence and optimizing resource utilization.

1.2 TWTG's Technological Approach

TWTG has played a crucial role in the I-IoT revolution, especially for energy and chemicals companies. They recognized the transformative potential of

LoRaWAN technology early on and embarked on a journey to leverage it to improve operational efficiency and safety in the sector. Their approach has helped lay the foundation for transitioning traditional operational frameworks into more advanced and data-driven paradigms.

1.3 TWTG's SolidRed I-IoT Platform and NEON Sensor Suite

Central to TWTG's I-IoT strategy is the SolidRed I-IoT platform, a robust framework designed to facilitate seamless integration and communication between various I-IoT devices. NEON is TWTG's LoRaWAN-based sensor range – a sophisticated sensor suite tailored to the energy industry's specific demands. The NEON products are engineered not only for performance but also for ease of retrofitting onto existing equipment. By making previously non-intelligent equipment smart and capable of providing data to aid engineers in making informed decisions about the status of operations and future maintenance.

1.4 Future Integration of Sensor Fusion Technology in NEON Sensors

In early 2024, TWTG will elevate its NEON sensor range by integrating advanced sensor fusion technology. This significant technological update will introduce two key features: *TimeSync* and *EventSync*, both designed to enhance data accuracy and synchronization across industrial applications.

Ongoing, all compatible NEON sensors from TWTG will benefit from sensor fusion functionality from 2024 onwards. To extend these advancements to the existing NEON sensors already in operation, TWTG will offer these new features through software updates, ensuring that every compatible sensor benefits from the latest I-IoT technology.

1.5 TWTG Products in this White Paper

In order to demonstrate sensor fusion, NEON products assume a specialized role in this white paper. These advanced sensors and devices are utilized as the apparatus in conducting the simulations that illustrate the principles and practicality of sensor fusion. These simulations are integral to showcasing how sensor fusion can be effectively operationalized in real-world industrial contexts. The role of NEON products in these experiments is to exemplify the application and benefits of sensor fusion technology, highlighting their functionality beyond their primary operational use.

1.6 Objective of the White Paper

This white paper explores the intricacies and advantages of time synchronization for NEON sensors over the LoRaWAN network – an essential aspect of sensor fusion approach. This paper explores how this technology redefines the operational efficiency and safety standards in the energy industry and what is conceptually possible in terms of insights. Through a combination of technical analysis, case studies, and practical examples, this document will demonstrate the transformative power of synchronized sensor fusion, highlighting its potential to shape contemporary industrial operations as this sector reinvents its methodology and objectives for a future era.

2. Concept of Sensor Fusion

2.1 What is Sensor Fusion?

Sensor fusion, in its most fundamental terms, works by integrating data from multiple sensors distributed throughout a facility or system. These sensors, which can vary in type and function, collect various data points, such as temperature, pressure, vibration, and flow rates. The fusion process involves aggregating and synchronizing this data to create a unified, comprehensive view of the system's operations.

Advanced algorithms analyze these combined data streams to identify patterns, correlations, and anomalies that might not be apparent when considering data

Figure 1. Operational NEON Sensors installed at industrial facilities

from individual sensors in isolation. This holistic approach allows for more accurate monitoring, predictive maintenance, and decision-making. However, while sensor fusion's functionality is straightforward, its true potential lies in creating new levels of understanding.

Venturing beyond its basic functionality, sensor fusion represents a significant leap in industrial engineering, especially in managing energy production facilities and complex operations. This technology potentially provides engineers with a comprehensive and integrated view of their entire facility, enabling them to comprehend interconnected systems and operations as a single entity for the first time.

By merging previously distinct processes and equipment, sensor fusion allows engineers to examine and understand complex relationships and dependencies. For instance, the operation of pumps in different areas can directly impact the stability of pipelines located far away, making hidden impacts and interactions visible. This comprehensive view helps engineers identify and address issues previously concealed by the complexity of separate systems. Furthermore, by integrating external environmental factors such as weather conditions, sensor fusion can allow for more informed maintenance schedules and operational decisions, which enhances efficiency and reduces downtime.

In essence, sensor fusion opens up possibilities for understanding and optimizing industrial operations. It provides engineers with previously unattainable insights and control, marking a new era in managing and maintaining industrial facilities.

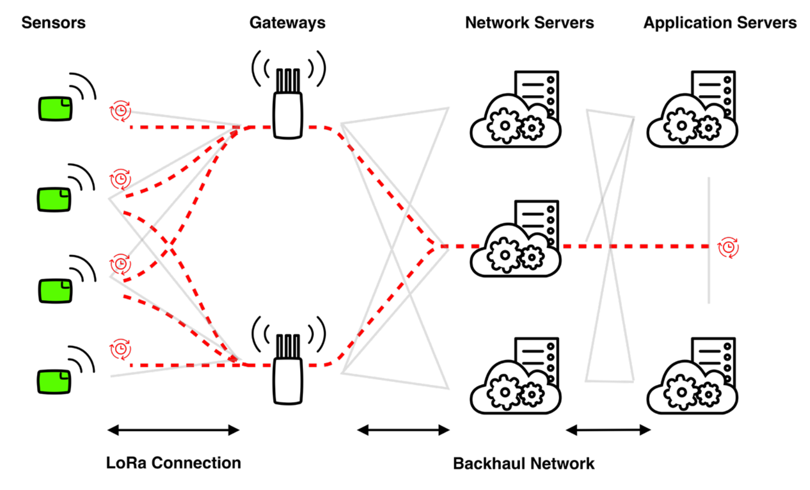

Figure 2. The LoRaWAN Network architecture with its core elements and multiple sensors. Sensor fusion uses this standard architecture to synchronize a time stamp between multiple sensors to provide a more precise, dependable, and comprehensive understanding than what would be achievable with data from a single sensor.

3. Time Synchronization (NEON TimeSync)

3.1 Advancing Sector I-IoT with Time Synchronization

Sensor fusion is poised to play a vital role in the future expansion of I-IoT within the sector. At its most basic, sensor fusion combines data from multiple sensors to provide a more precise, dependable, and comprehensive understanding than what would be achievable with the data from a single sensor.

At TWTG, we've advanced the concept of sensor fusion by creating a new functionality: Time Synchronization (or *TimeSync*). This innovation is a critical element for data congruency and real-time monitoring. *TimeSync* is highly configurable, allowing optimal balance between synchronization frequency and data accuracy. Typically, our system is set to synchronize once every day. This frequency has been chosen strategically, considering the network bandwidth and synchronization precision trade-offs. By syncing daily, we can maintain a maximum time error margin of only 11.8 milliseconds across our sensor network (See Figure 3). This level of precision is significant for effective monitoring and predictive maintenance in the energy industry and chemicals sector.

Powered by the devTimeReq of LoRaWAN, this daily synchronization ensures that sensors are accurately synchronized and operate optimally, conserving energy and network bandwidth.

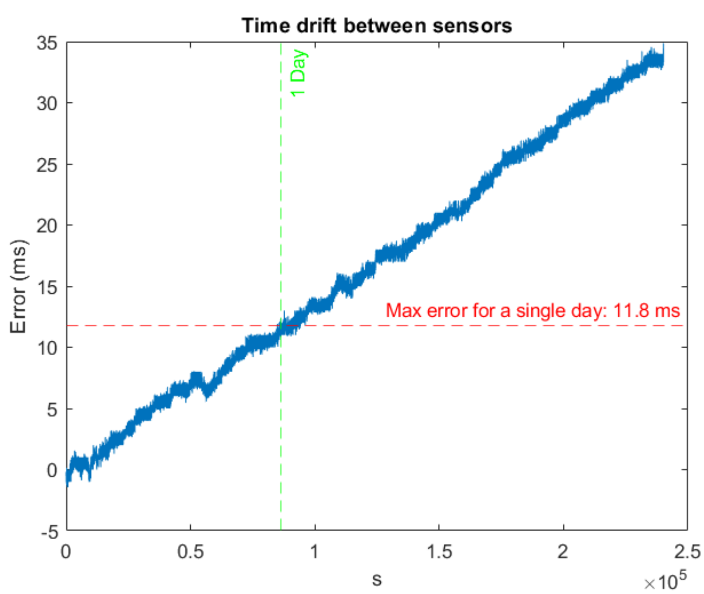

Figure 3. Time drift for a single sensor with one synchronization event per day

3.2 Mitigating Message Collisions in Synchronized I-IoT Networks

Managing the risk of message collisions becomes essential in environments where large groups of I-IoT devices operate in synchronization. At TWTG, we have developed a technological approach to mitigate this challenge by separating the timing of measurement and the transmission of its result.

This way, when a device measures something, it doesn't immediately send that information. Instead, a random amount of time is calculated before being sent. This approach reduces the risk of multiple devices trying to send data simultaneously. Separating the measurement and transmission events and introducing a random transmission time minimizes the likelihood of collisions. This strategy works particularly well in dense sensor networks where many devices increase the potential for collisions.

The strength of this approach lies in its simplicity and versatility - easily applied in multiple industrial environments without complex coordination mechanisms. As a result, it provides a robust and scalable solution that enhances the dependability of our IIoT networks. This is critical for ensuring uninterrupted data flow for real-time monitoring and decision-making in the oil and gas industry.

3.3 Scheduling in Synchronized I-IoT Networks

One key feature of our solution is its Scheduling Function. Designed to provide users with enhanced control over the timing and frequency of measurements, this function reflects our commitment to delivering tailored solutions that meet the specific needs of the energy industry.

3.3.1 Precise Scheduling of Measurements

Users can schedule measurements for a specific time and day of the week. This capability is not limited to a one-time measurement; it extends to the ability to set up recurring measurements. Such precision in scheduling is crucial for operations where data needs to be collected at specific intervals or during certain operational conditions. It enables more efficient planning and better alignment with operational cycles. The Schedule Function allows users to schedule measurements for specific times and days of the week. Users can set up recurring measurements, as capability is not limited to one-time measurements. This feature is crucial for operations where data needs to be collected at specific intervals or during certain operational conditions. It enables more efficient planning and better alignment with operational cycles.

3.3.2 Minimum Value Threshold for Transmission

Another aspect of the Schedule Function is the ability to set a minimum value threshold for data transmission. This threshold helps filter out non-essential messages, such as data from machines not operating. By setting a threshold, the system only transmits data when it meets or exceeds this predefined value. This functionality is beneficial in scenarios where continuous monitoring might result in the transmission of redundant or irrelevant data, such as when machinery is turned off or operating below a certain threshold. It not only saves bandwidth but also ensures that the focus remains on critical and meaningful data.

3.4 User-friendly interface

The Schedule Function has a user-friendly interface that enables greater flexibility and efficiency in data management. It allows users to define exact parameters for data collection and transmission, enhancing sensor fusion effectiveness in I-IoT. This feature reflects our commitment to providing solutions that are not only technologically advanced but also highly adaptable to our client's unique operational needs. The device randomly chooses an interval between two consecutive measurements and transmits its results during this time.

4. Event Synchronization (NEON EventSync)

4.1 TWTG's EventSync Innovation

In this section, we explore another innovation in sensor fusion - TWTGs Event Synchronization (*EventSync*). Managed via TWTG's I-Iot platform, SolidRed, *EventSync* has unique capabilities in managing group dynamics among devices on LoRaWAN networks.

4.2 Formation of Device Groups

SolidRed has the capability to put devices into groups. However, these groups can be distinct; this means devices do not have to be actively connected or even be in communication with each other. Instead, they function independently while being part of a collective group.

4.3 Group Recognition by SolidRed

Part of the intelligence of SolidRed lies in its ability to recognize device groups. For SolidRed, the existence of a group is defined by its awareness that certain devices are collectively associated, although they operate independently.

4.4 Buffering and Timestamping of Measurements

Each device in the group maintains a buffer of previous measurements, including the timestamps when these measurements were taken. This historical data is crucial for contextual analysis and for understanding the sequence of events in case of any anomalies.

4.5 Trigger-Based Alert and Data Request Mechanism

The SolidRed system was designed to respond quickly to triggers from any device in a group through the EventSync process. If a device sends an alert message to SolidRed indicating an unusual event or measurement, SolidRed requests historical data from all devices in the group. This request specifically focuses on the timestamp of the alerted device's measurement (See Figure 4). By doing so, a comprehensive analysis of the situation can be carried out by considering the data from all devices at the time of the event.

Timestamped Measurements

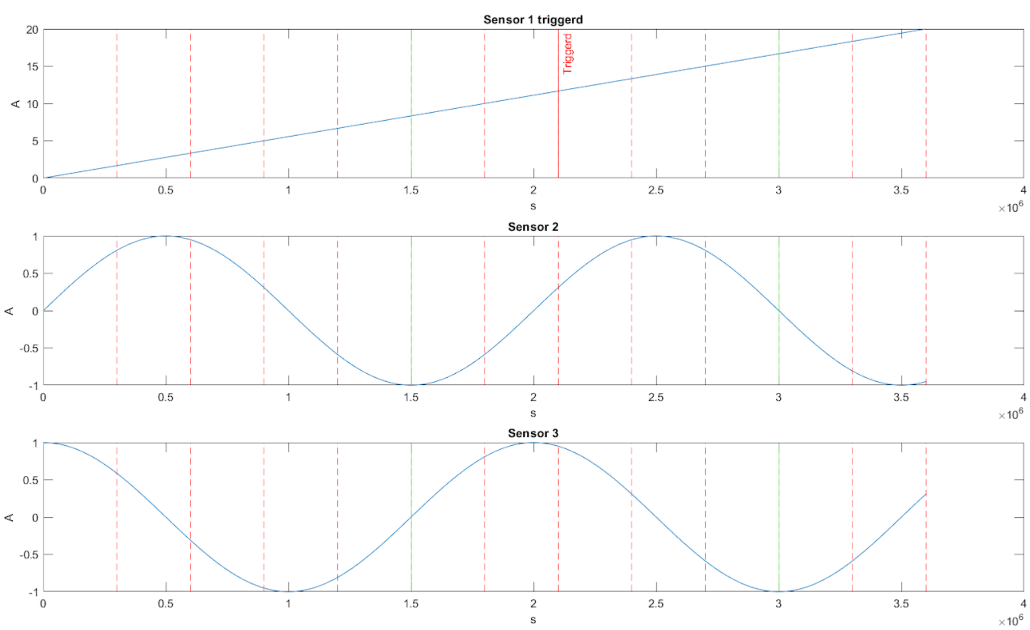

Figure 4. Synchronized NEON Sensors analyzing historical data

5. Advantages of Synchronized Measurements in I-IoT Systems

This section examines the significant advantages of synchronized measurements in the Industrial Internet of Things, especially in the energy industry and chemicals sector.

5.1 Foundation for Digital Twin Realization

The ability to synchronize measurements is crucial in creating an accurate and real-time snapshot of an asset, using a set of sensors. This capability is essential for achieving a digital twin, which is a virtual model that mirrors the physical asset. By ensuring that all sensor data is precisely time-aligned, we can generate a comprehensive and accurate representation of the asset's current state. This level of detail and accuracy is indispensable for predictive maintenance, performance optimization, and decision-making processes.

5.2 Crucial for Integrating Sensors in Variable Conditions

n dynamic operational environments that are constantly changing, it is crucial to have synchronized measurements. This ensures that the data from different sensors is aligned in real time and accurately reflects the current state of the process. Without synchronization, sensors have no context with one another (See Figure 5 on the next page).

Synchronization is particularly important when integrating different types of sensors as it allows for a reliable interpretation of the asset's condition and performance. Once synchronized, an engineer can immediately see what occurred at the moment of an event across the synchronized sensor set, giving them a far more precise picture of the circumstances (See Figure 6).

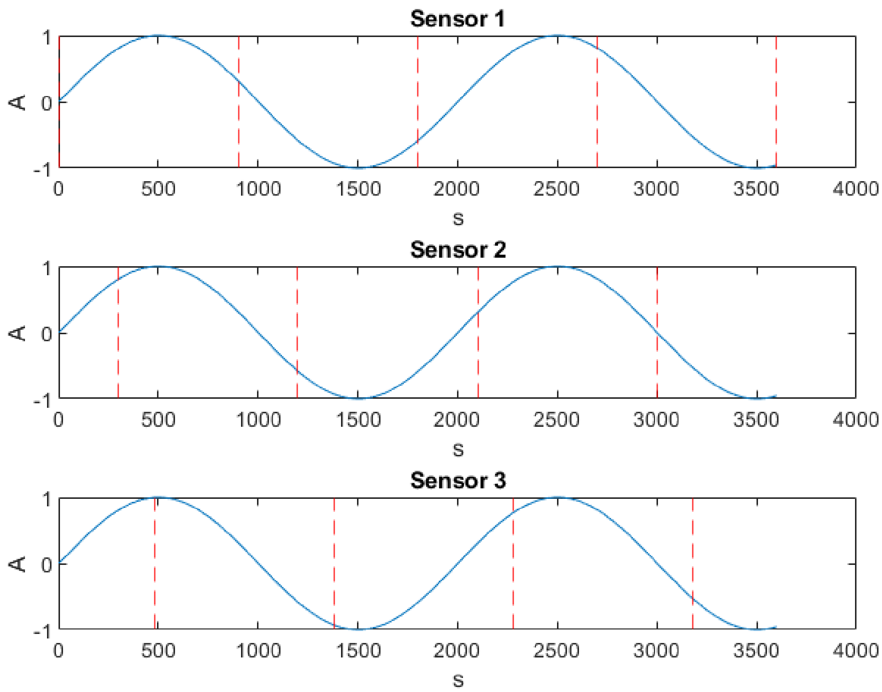

Figure 5. Sensors without Synchronization. The red dotted line indicates the moment of measurement. Indicating that, while the measurement is valuable, the data between sensors 1,2 and 3 are not comparable.

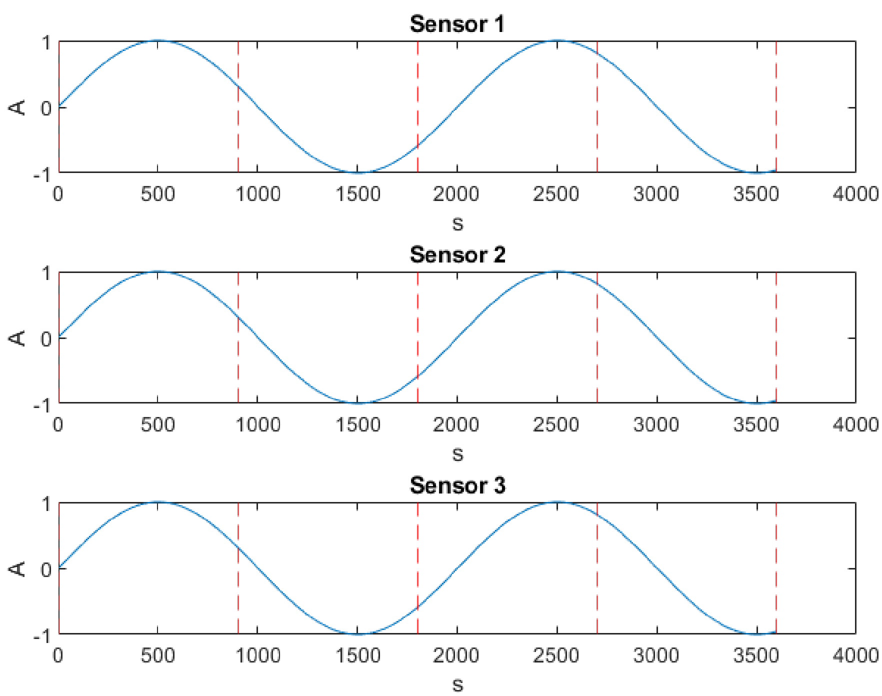

Figure 6. NEON Sensors after Synchronization. Here all sensors measure at a synchronized moment (red dotted line). This results in valuable information per sensor, and the data can also be compared and bundled with the other sensor values.

5.3 Enhanced Asset Analysis During Alert Conditions

Synchronizing events and measurements is crucial during alert conditions. When an anomaly or a critical event is detected, data from various sensors are combined to provide a comprehensive view of the asset in question. This view is essential to diagnose issues, understand the scope of the event, and implement the appropriate response strategies. It ensures that decisions are made based on a complete and accurate understanding of the asset's status.

Overall, incorporating synchronized measurements in IIoT solutions not only improves the precision and dependability of the collected data but also boosts the overall operational intelligence of the oil and gas sector. By offering a comprehensive and up-to-the-minute view of assets, we equip our clients with the vital knowledge required for effective and proactive asset management.

6. Implications and Future Directions

6.1 The Strategic Impact of Sensor Fusion Technology

Technological innovations, such as Sensor Fusion, are significantly transforming the oil and gas industry. These developments are introducing a new era of operational excellence marked by increased efficiency, enhanced safety, and improved predictive maintenance. The precision and reliability of synchronized sensor data not only enable more accurate monitoring and analysis, leading to optimized processes and reduced wastage but also bolster safety measures by allowing real-time detection and response to operational anomalies. This reduces the risk of accidents and environmental hazards.

Furthermore, sensor fusion technology is a strategic advancement, moving beyond traditional operational methods towards more intelligent, efficient, and sustainable practices. It enhances predictive maintenance, thus minimizing downtime and extending equipment lifespan, which results in substantial cost savings and operational resilience. This aligns with the industry's growing focus on environmental responsibility and sustainability, as efficient resource utilization and reduced incident rates contribute to a lesser environmental impact.

The technology empowers operators with deeper insights, facilitating informed decision-making, streamlined workflows, and innovation. This evolution addresses the industry's current challenges, including the need for efficient extraction methods, compliance with environmental regulations, and the integration of renewable energy sources, marking a transformative phase in the industry's journey toward sustainability and efficiency.

6.2 Future Innovations

The potential for further advancements in sensor fusion technology is vast and holds promise for even more sophisticated analytical capabilities and operational insights. The convergence of sensor fusion with emerging technologies such as artificial intelligence (AI), machine learning, and edge computing could lead to more advanced data analysis and autonomous decision-making processes. This integration could enable real-time adaptive responses to changing operational conditions, further enhancing efficiency and safety..

6.3 Upcoming Feature: Class B for Direct FFT Request

TWTG is set to introduce a new feature, Class B for Direct FFT Request, which will further enhance the capabilities of its sensor fusion technology. This feature is designed to provide more precise control over data collection and analysis, enabling even more detailed and accurate insights into operational conditions.

7. Conclusion: Advancing Industrial Operations through Sensor Fusion Technology

This white paper has highlighted TWTG's significant contributions to sensor fusion within I-IoT, particularly its impactful applications in the energy sector. Through innovations like time synchronization over the LoRaWAN network and the integration of the SolidRed I-IoT platform with NEON products, TWTG has demonstrated a powerful synergy of technological advancement and practical application. This combination is set to transform the operational data landscape in industrial settings.

Key to this transformation is the role of sensor fusion in enhancing data congruency and real-time monitoring. By aligning diverse sensor data, TWTG's technology not only improves accuracy but also amplifies the relevance of the information gathered. This is further reinforced by protocols for daily recalibration and lag time management, which are integral to predictive maintenance and informed operational decision-making.

Practical examples, like the heat exchanger efficiency simulation, have underscored the tangible benefits of synchronized data, particularly in enhancing operational efficiency and reliability. Furthermore, the development of event synchronization builds upon the foundations of sensor fusion, creating a more nuanced and effective approach to monitoring and decision-making in response to specific operational events.

Looking ahead, the potential of sensor fusion technology in industrial applications is immense. The integration with emerging technologies such as AI and machine learning is anticipated to expand analytical capabilities and insights significantly. Additionally, the upcoming feature of Class B for Direct FFT Request signals TWTG's dedication to continuous innovation in the realm of I-IoT.

In essence, TWTG's advancements in sensor fusion technology represent a crucial development in the I-IoT domain, with far-reaching implications for industrial operations. This technology not only advances operational efficiency, safety, and sustainability but also aligns with global trends toward more intelligent and environmentally responsible industrial practices. The ongoing evolution of these technologies is expected to play a pivotal role in shaping the future of industrial operations and contributing to a more sustainable and efficient industrial landscape.

Figure 7. From 2024 onwards, all compatible NEON sensors from TWTG, such as the NEON Vibration Sensor depicted here, will benefit from sensor fusion functionality including TimeSync and EventSync, both designed to enhance data accuracy and synchronization across industrial applications.

For more,
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