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Q1: Propose an overall design for the system, mainly focusing on the communication technology to be used. Motivate your choice.
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For this IoT system in a small indoor bacterial cellulose factory, ZigBee could be an appropriate choice for communication technology due to the following characteristic:

Low Hardware Cost: ZigBee modules and development kits are cost effective compared to alternatives, they typically integrated microcontrollers, radios, and ZigBee protocol stacks, reducing the need for additional components.

Low Power Consumption: ZigBee operates on low power, making it suitable for devices that need to operate for extended periods without frequent battery changes. Since the bacterial cellulose growing process takes around 14 days, low power consumption is essential to ensure continuous monitoring without frequent interruptions for battery replacements.

Mesh Networking: ZigBee supports mesh networking, each ZigBee device (such as sensors monitoring luminosity, sugar content, and pH sensors) can communicate directly with nearby devices or through intermediate nodes (i.e. other ZigBee devices) to reach the central monitoring system. This mesh topology ensures reliable communication even if some devices are out of direct range, as messages can hop through intermediate devices.

Reliability: ZigBee operates in the 2.4 GHz frequency band and employs a robust mesh network topology, which helps mitigate interference and ensures data integrity even in noisy environments like laboratories.

Scalability: ZigBee networks can accommodate many devices, making it suitable for environments with multiple sensors like the bacterial cellulose factory with 20 growing basins. As the factory expands, additional sensors can be easily integrated into the existing ZigBee network.

Ease of Implementation: ZigBee offers a standardized protocol stack, simplifying the deployment of IoT solutions. There are also many off the shelf ZigBee modules and development kits available, reducing development time and cost.

CSMA/CA: ZigBee uses CSMA/CA to manage access to the shared communication medium and avoid collisions between packets. Before transmitting data, a ZigBee device listens to the channel to detect ongoing transmissions. If the channel is clear, the device proceeds with the transmission. If the channel is busy, the device waits for a random backoff period before attempting to transmit again. This mechanism helps prevent interference and ensures fair access to the channel for all devices in the network. In the bacterial cellulose factory, each sensor node can use CSMA/CA to access the communication channel and transmit data to the central monitoring system without causing interference with other devices.

Route AODV: AODV is a routing protocol for ZigBee based mesh networks, established only when needed. When a sensor node wants to send data to the central monitoring system, it broadcasts a RREQ packet.

Intermediate nodes receiving the RREQ either forward it or reply if they have a route to the destination. Through this process, a route is established from the source to the destination, and subsequent data packets follow this route. In the bacterial cellulose factory, AODV can be used to dynamically establish routes between sensor nodes and the central monitoring system, adapting to changes in the network topology or node failures.

In addition to ZigBee, other essential communication technology for the system include:

Sensor Nodes: Each bacterial cellulose basin will be equipped with a sensor node capable of measuring luminosity, sugar content and pH level. These sensor nodes will periodically collect data at hourly intervals.

Central Monitoring System: Component of the system responsible for collecting, processing, and analyzing data from the sensors. It's a gateway device equipped with ZigBee communication capabilities. The central monitoring system aggregates data from multiple sensors, performs analysis to monitor the production process, and provide a user interface for visualization and control.

Database: The database stores the collected sensor data for historical analysis and reference

Monitoring interface: Accessible by researchers and operators through the central monitoring system, this interface provides functionalities such as real-time data visualization, anomaly detection, and control of environmental parameters in the production process.

Overall, ZigBee's cost effectiveness, low power consumption, mesh networking, reliability, scalability, ease of implementation, and advanced communication protocols make it an ideal choice for monitoring the production process in a small indoor bacterial cellulose factory.