

Unit II: Clinical Patient Monitoring

7. Patient Monitoring Systems

7.1 Multi-Parameter Patient Monitor (MPM)

A Multi-Parameter Patient Monitor continuously acquires, conditions and displays vital signs from one patient in real time, and raises an alarm if any value drifts outside a safe range.

The four core vital signs typically monitored:

- Heart Rate
- Blood Pressure
- Respiration Rate
- SpO₂ (blood oxygen saturation)

Why it matters: continuous ICU/OT surveillance, early automated detection of patient deterioration, and reduced manual/periodic-charting burden on nursing staff.

MPM Signal Chain

Sensors → Signal Conditioning (amplification, filtering) → ADC → Processor/DSP (rhythm/parameter extraction) → Display & Alarm — often with a parallel network linking multiple bedside units to a Central Monitoring/CCU Station.



Fig 7.1 — General MPM signal chain from sensors to central monitoring station (Sensors: ECG electrodes, BP cuff, SpO₂ probe, respiration belt → Signal Conditioning: instrumentation amplifier, filtering, isolation → ADC: analog signal digitised at fixed sampling rate → Processor/DSP: feature extraction, thresholding, alarm logic → Display & Alarm: waveforms, numerics, visual/audible alerts; parallel network feed to Central Monitoring / EHR Station)

Historical Evolution of Patient Monitors

- **1960s:** single-channel ECG bedside 'oscilloscope' monitors.
- **1970s–80s:** cardiometers and the ICU concept develop; multiple bedside digital monitors appear.
- **1990s–2000s:** interconnected, hospital-wide networked monitoring emerges.

Smart Alarming & AI-based Correlation

Modern MPMs correlate multiple vital-sign parameters together (rather than alarming on any single threshold breach independently) to reduce false alarms and improve alarm specificity — e.g., a classifier trained/tested on the MIMIC-III ICU dataset improved specificity from ~91% to ~99% while retaining high sensitivity.

A Representative IoT-based Patient Monitor Architecture

Temperature sensor (DS18B20), pulse-rate sensor (SEN-11574) and blood pressure sensor (Omron-8712) feed an ATmega 32A microcontroller, which connects to a Wi-Fi module (ESP8266) and AP router → cloud → MQTT protocol → Android app → doctor-side personal computer.

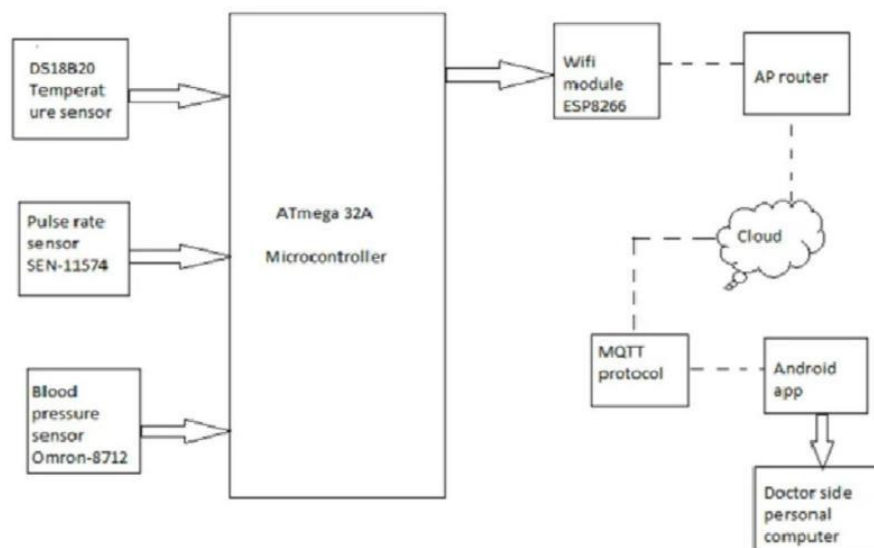


Fig 7.2 — Example IoT patient-monitor block diagram: temp/pulse/BP sensors → microcontroller (with Wi-Fi module) → MQTT protocol → cloud → doctor's dashboard/app

Emerging Trends

- AI-driven predictive alerts (deterioration prediction ahead of clinical events).
- Wireless, wearable multi-parameter patches replacing wired bedside sensors.
- IoT & cloud-connected platforms for remote multi-patient dashboards.
- Contactless & radar-based sensing (no skin contact required).

7.2 ICU Monitoring System

ICU monitoring addresses the cardiovascular, pulmonary and neurological systems of critically ill patients, with the primary goal of maintaining stable cardiopulmonary function and optimal oxygen transport. Monitoring in the ICU is broadly grouped as:

1. Haemodynamic monitoring
 - o (a) Non-invasive haemodynamic monitoring
 - o (b) Invasive haemodynamic monitoring
2. ICP (Intracranial Pressure) monitoring

(a) Non-Invasive Haemodynamic Monitoring

Commonly monitored parameters: temperature, heart rate, blood pressure, oxygen saturation and respiration.

1. **Sphygmomanometer (BP cuff)** — indirectly measures arterial blood pressure using an inflatable bladder in a non-distensible cuff with a pressure manometer (aneroid or automatic/oscillometric); manual cuff use requires Korotkoff-sound auscultation over the brachial artery.
2. **Telemetry (ECG monitoring)** — continuous HR, rhythm and respiratory-rate monitoring via wireless chest electrodes transmitting to a central/remote receiver.
Clinical caution: poor signal quality from artifact, patient movement, or bronchodilator therapy can be misread as arrhythmia.
3. **Pulse oximetry** — non-invasive %SpO₂ measurement via a finger/ear/nose probe using differential red/IR light absorption; SpO₂ ≤ 88% indicates need for supplemental O₂, and the pulse reading should match ECG/palpated pulse.

(b) Invasive Haemodynamic Monitoring

1. **Arterial line (A-line)** — a non-tapered Teflon catheter (brachial, radial, or femoral artery) connected to a transducer for continuous, real-time systolic/diastolic/MAP display and repeated arterial blood sampling. *Risk:* significant blood loss or line displacement/bleeding at the insertion site.
2. **Central Venous Catheter (CVC)** — indicated when significant fluid loss occurs, and used as a guide to overall fluid balance; CVP reflects right-heart function. Placed via subclavian, basilic, jugular or femoral vein, terminating in the superior vena cava; also used for parenteral nutrition, repeated blood sampling, large fluid volumes, or transvenous cardiac pacing.
3. **Pulmonary Artery Catheter (Swan-Ganz / PA catheter)** — a balloon-tipped, multi-lumen catheter passed via a central vein through the right atrium and ventricle into the pulmonary artery. Directly/indirectly measures PAS, PAD, PAP, LAP, RAP, core body temperature, cardiac index (CI) and cardiac output (CO) — used in haemodynamically unstable cases (ARDS, cardiogenic shock, acute MI, heart failure).

ICP (Intracranial Pressure) Monitoring

- Indicated for ICU patients with head injury, hypoxic brain damage, cerebral tumour, or post-neurosurgery — raised ICP restricts cerebral blood flow and can cause further brain damage.
- **Cerebral Perfusion Pressure: $CPP = MAP - ICP$.**
- Clinically, raised ICP is suspected from altered consciousness, abnormal BP, pupillary response, temperature and respiration changes.

Types of ICP monitors:

1. **Epidural sensor** — fibre-optic/pneumatic sensor placed in epidural space; not adjustable after placement (needs repositioning if drift occurs); fair reliability.
2. **Subarachnoid bolt** — hollow bolt through a burr hole into the subarachnoid space; level determined by physician; poor reliability, decreased accuracy at high ICP readings.
3. **Fibre-optic tipped catheter (parenchymal)** — placed in ventricle, parenchyma, subdural or subarachnoid space, or under a bone flap; not adjustable after placement; very reliable.
4. **Intraventricular catheter (ventriculostomy)** — the gold standard; allows CSF sampling and drainage, and can administer medication directly. Complications can include infection, meningitis, ventricular collapse, or catheter occlusion by blood/brain tissue.

Quick Revision — Patient Monitoring

- MPM core vitals: Heart rate, Blood pressure, Respiration rate, SpO₂.
- ICU monitoring = Haemodynamic (non-invasive + invasive) + ICP monitoring.
- Invasive haemodynamic: A-line (arterial BP), CVC (CVP/right-heart), PA/Swan-Ganz catheter (PAP, CO, CI).
- ICP gold standard = intraventricular catheter (ventriculostomy); $CPP = MAP - ICP$.

Reference: R.S. Khandpur, Handbook of Biomedical Instrumentation, 3rd Edition (McGraw-Hill Professional, 2014). Lecture slide decks 2.1–2.5, Advanced Biomedical Instrumentation, prepared by Threase Sopra A., AP/DoBM.