APIs Overview for Arduino

UNO R4 WiFi • REST • MQTT • Security • Best Practices

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Why APIs for Arduino?

APIs (Application Programming Interfaces) are the bridge between your Arduino and:

- Cloud services & databases (data logging, analytics, dashboards)
- Mobile / web apps (real-time monitoring & control)
- Other devices (gateway nodes, microservices)

Smart Garden example: DHT11 + soil sensor $\rightarrow$ publish via API $\rightarrow$ store & visualize $\rightarrow$ alerts & ML predictions.

API Communication Models

Type	Protocol	Direction	When to use
REST API	HTTP/HTTPS	Client→Server	Simple JSON posts, easy web back (FastAPI/Flask/Supabase).
MQTT API	TCP/TLS	Pub/Sub (bi-dir)	Low-power IoT telemetry, scalable, mands via topics.
WebSocket	TCP	Bi-directional	Realtime dashboards pushing updat browsers.
GraphQL	HTTP/HTTPS	Client→Server	Query only the fields you need; less mon on MCUs.

REST APIs

REST: Concept

Endpoints: `/ingest`, `/telemetry`, `/status` **Methods:** `GET`, `POST`, `PUT`, `DELETE`

Typical flow

1. Arduino formats sensor data as JSON.
2. Sends HTTPS `POST` to server endpoint.
3. Server authenticates (API key), validates schema, stores data.
4. Optional: server responds with status or commands.

UNO R4 WiFi: Minimal HTTPS POST (REST)

Libraries: WiFiS3, ArduinoHttpClient

```
#include <WiFiS3.h>
#include <ArduinoHttpClient.h>

const char* SSID = "YOUR_SSID";
const char* PASS = "YOUR_PASS";

const char* HOST = "api.example.com";
const int   PORT = 443; // HTTPS
const char* API_KEY = "YOUR_LONG_RANDOM_KEY";

WiFiSSLClient net;          // TLS
HttpClient    client(net, HOST, PORT);

void setup() {
```

FastAPI: Simple Ingest Endpoint (Server)

```python
from fastapi import FastAPI, Request, HTTPException

app = FastAPI()
EXPECTED = "YOUR_LONG_RANDOM_KEY"

@app.post("/ingest")
async def ingest(req: Request):
    auth = req.headers.get("authorization", "")
    if not auth.startswith("Bearer ") or auth.split(" ", 1)[1] != EXPECTED:
        raise HTTPException(status_code=401, detail="invalid api key")

    data = await req.json()
    # TODO: validate schema & ranges, then write to DB
    return {"ok": True, "size": len(str(data))}
```

MQTT APIs

MQTT: Concept

Broker-centric pub/sub

- Devices *publish* telemetry to topics.
- Dashboards/servers *subscribe* to topics.
- Lightweight, low bandwidth, great for fleets.

Topic design

```
bhcc/smartgarden/SOIL1/telemetry
bhcc/smartgarden/SOIL1/status
bhcc/smartgarden/SOIL1/command
```

Flow

```
[UNO R4] --publish--> [MQTT Broker
    ]
      \                    /
       \--subscribe<-----/
           [Server/Dash]
```

UNO R4 WiFi: MQTT over TLS

Libraries: WiFiS3, ArduinoMqttClient

```
#include <WiFiS3.h>
#include <ArduinoMqttClient.h>

const char* SSID = "YOUR_SSID";
const char* PASS = "YOUR_PASS";
const char* BROKER = "broker.example.com";
const int   PORT   = 8883;  // TLS
const char* USER   = "SOIL1";
const char* TOKEN  = "YOUR_LONG_RANDOM_KEY";

WiFiSSLClient net;
MqttClient    mqtt(net);

void setup() {
  WiFi.begin(SSID, PASS);
```

WebSockets (optional)

WebSockets: When to Use

- Real-time dashboards pushing updates to browsers.
- For Arduino, typically proxied via a gateway (ESP32/PC server).
- Security and framing overhead can be higher than MQTT.

Authentication & Security

API Keys & Practical Security

API key placement

- HTTP header: `Authorization: Bearer` *KEY* (recommended)
- Query string: `?api_key=KEY` (only if service requires)
- MQTT username/password: `user=deviceId`, `pass=KEY`

Checklist

1. Use **TLS** (HTTPS / MQTT over TLS).
2. One **unique key per device**; rotate keys.
3. Server-side **validation**: schema, ranges, rate limit.
4. Include **timestamps**; reject stale data.
5. Avoid printing secrets on Serial in production.

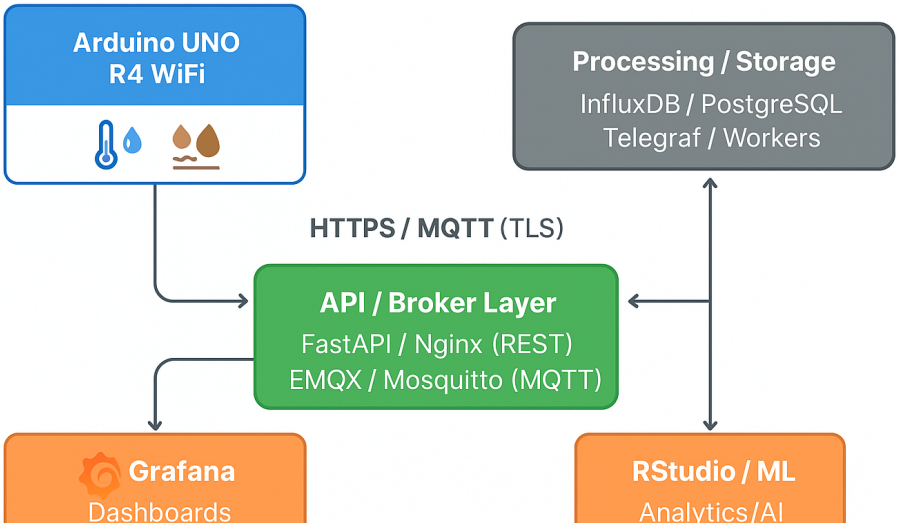
Best Practices

Robustness & Data Quality

- **Retry buffers**: cache unsent readings when offline.
- **QoS 1** for MQTT telemetry; use retained only for last-known status.
- **Batch uploads**: send N readings per POST to reduce overhead.
- **Retention policies**: downsample older data in TSDB (e.g., InfluxDB).
- **Observability**: add device status pings and error counters.

Architecture

End-to-End Reference Architecture



Practical Examples

Service Examples & Endpoints

Platform	Method	Example
ThingSpeak	REST	`/update?api_key=XXX&field1=23.5`
Arduino IoT Cloud	MQTT	`deviceId/variableName` (provisioned)
Supabase (Postgres)	REST	`/rest/v1/sensors` (insert JSON rows)
Custom (FastAPI)	REST	`/ingest`, `/telemetry`

JSON Payload Template

```
{
  "ts": 1730132405,
  "nodeId": "SOIL1",
  "temperature": 23.8,
  "humidity": 41.2,
  "soilMoisture": 0.31,
  "vbat": 4.86,
  "rssi": -62
}
```

Tip: Keep field names short but clear; include a UNIX timestamp and a device identifier.

Troubleshooting

Common Issues & Fixes

Symptom	Fix
`connection failed` / **timeouts**	Verify SSID/password, DNS/host, open outbound ports (443/8883).
`401/403 Unauthorized`	Check API key location (header vs query), token validity/rotation.
Duplicate MQTT data	Ensure retained flag is off for telemetry; use QoS1 only if needed.
Malformed JSON	Validate braces/quotes; avoid trailing commas; check decimal dots.
Clock skew / stale data	Sync NTP or include controller timestamp; reject stale on server.

Advanced Extensions

Beyond the Basics

- **OTA updates**: Arduino IoT Cloud or custom HTTPS fetcher.
- **JWT / HMAC**: signed requests (anti-replay, integrity).
- **Edge batching & compression**: send fewer, larger posts.
- **Alerts**: Grafana/Influx tasks or server rules (email/Telegram).
- **AI loop**: export to CSV $\rightarrow$ RStudio/ML $\rightarrow$ predictions via API.

Summary

Key Takeaways

- REST = simplest path to any web backend; MQTT = best for IoT scale.
- Use TLS, per-device API keys, and server-side validation.
- Design clean topics/endpoints and stable JSON schemas.
- Plan dashboards, retention, and ML integration from day one.

References

- Arduino Docs — `https://docs.arduino.cc`
- MQTT — `https://mqtt.org`
- ThingSpeak — `https://thingspeak.com/docs`
- InfluxData — `https://www.influxdata.com`
- FastAPI — `https://fastapi.tiangolo.com`

Questions?

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