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Intelligent Communication Resource Management in IoT Fire Detection: Integrating USSD Balance Monitoring with Tiered Emergency Notification

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Abstract— *This paper presents an intelligent communication architecture for IoT-based fire detection that addresses a constraint specific to prepaid-dominated mobile markets: an emergency-notification channel built on SMS can fail silently if the sending SIM's airtime balance is depleted. The prototype combines automated USSD balance checking with a tiered notification scheme, built around a SIM900A GSM/GPRS module and an Arduino Uno microcontroller, and fuses three detection modalities, a KY-026 flame sensor, a DS18B20 digital temperature sensor, and an MQ-6 gas sensor, with fixed thresholds (45°C; an MQ-6 reading corresponding to approximately 500 ppm) chosen to limit nuisance triggers from ordinary residential temperature swings. Alerts escalate across three activation levels according to how many of the three sensors are concurrently triggered, each with a distinct buzzer pattern and recipient list, plus an automatic "all-clear" message once conditions normalise. SIM balance is checked over USSD using the unified *310# code at system start-up and, thereafter, whenever more than four hours have elapsed since the last successful check at the moment an alert is due; the retrieved balance is appended as plain text to every outgoing SMS. *310# is the balance-check code the Nigerian Communications Commission has harmonised across MTN, Airtel, Glo, and 9mobile, though this prototype was built and exercised on a single provider's SIM, so its behaviour on the other three networks was not independently confirmed. Bench testing in Jos, Plateau State, Nigeria, using controlled ignition sources (a lit mattress-foam swab, and a gas lighter or cylinder release) measured flame detection at roughly 52–156 ms across 10–100 cm, temperature-threshold detection at about 629 ms, and gas detection at roughly 6–17 s over the same range; a full-system demonstration in which all three thresholds were triggered together produced correct alarm escalation, dual-recipient SMS dispatch, and automatic reset once the stimuli were removed. Component-level current measurements (223.5 mA standby, 751.5 mA during an active alert) were used to calculate, not empirically confirm, an indicative runtime of roughly three days in standby and about one day of active-alarm operation from a 20,000 mAh power bank; because power-bank capacity is rated at cell voltage and delivered through a boost converter, actual runtime is expected to be lower than this first-order estimate. These results demonstrate a working low-cost prototype and a design pattern, USSD-based balance awareness fused with sensor-count-based tiered alerting, that is largely absent from the fire-detection literature reviewed for this work. They do not, on their own, establish detection accuracy, false-alarm rates, or cross-network communication reliability, which would require a study with defined fire and non-fire scenarios, negative controls, larger randomised trials, and multi-provider testing.*

Keywords— *GSM communication, USSD balance monitoring, emergency notification, IoT fire detection, prepaid mobile services, tiered alerting.*

I. INTRODUCTION

Emergency notification is a critical function of contemporary fire detection systems, allowing response personnel and property owners to be alerted quickly during a fire incident. Traditional fire alarm architectures rely on a local audible alert, which is of limited use when occupants are away from the monitored premises; cellular connectivity extends that reach to remote notification, but deploying it in developing-market contexts raises considerations that receive little attention in systems designed around postpaid billing assumptions.

Prepaid mobile service is the dominant subscription model across much of Africa, including Nigeria, in contrast to markets where postpaid billing predominates. A defining feature of prepaid service is that account-balance depletion can suspend outbound SMS without warning, a specific risk for any system whose emergency-notification path runs over that channel. As the review of related work in Section 2 shows, the fire-detection prototypes published in this space integrate GSM notification but do not address what happens to that notification path when the SIM's airtime runs out.

This research addresses that gap by combining an automated USSD-based balance check with a tiered notification scheme in a SIM900A/Arduino Uno prototype. Alert messages escalate through three levels depending on how many of three sensors (flame, temperature, gas) are concurrently triggered, and the system's currently cached SIM balance is appended to every outgoing SMS so that recipients also see the communication channel's status alongside the fire alert itself.

The contributions of this work are: (1) a working integration of automated USSD balance monitoring into a fire-detection alerting pipeline, targeting the prepaid-service constraint identified above; (2) a tiered notification design that differentiates single-sensor, dual-sensor, and confirmed triple-sensor conditions through distinct buzzer patterns and recipient lists, together with an automatic all-clear message; (3) adoption of the *310# balance-check code, harmonised by the Nigerian Communications Commission across Nigeria's four major providers by regulatory design, although only single-provider operation was exercised during development; and (4) bench-level characterisation of sensor response behaviour, alert-tier activation, and a first-order power budget for the resulting prototype.

II. Related Work

2.1 GSM-Based Fire Detection Systems

A number of recent Arduino- and microcontroller-based fire-detection prototypes combine multi-sensor detection with GSM-based remote notification, and each leaves a different part of the deployment problem unaddressed. Al Hasani et al. (2022) built an ESP8266-based mesh of fire-detection nodes that notified users and a fire department by SMS, reporting an average latency of about 20 seconds, but did not address backup power or an automatic-reset mechanism. Alqourabah et al. (2021) combined flame, temperature, and gas sensors on an Arduino Mega with an automatic water-sprinkler response and remote visualisation through the Ubidots platform, but did not report a power-consumption analysis or discuss automatic reset. Baba et al. (2022) paired flame, smoke, butane, and thermal sensors with both RF and GSM communication and a companion Android application, but recorded GSM notification delays averaging nearly 16 seconds, reported that the system shut down entirely on backup power, and likewise did not implement automatic reset. Hery et al. (2022) and Al Shereiqi and Sohail (2020) combined gas/smoke or smoke/temperature sensing with GSM or GSM-network notification but omitted flame sensing and backup-power analysis. Umaru and Tartisious (2023) used a programmable-logic-controller voting architecture for smoke detection with zone-specific suppression but did not address backup power or automatic reset, and Edozie et al. (2023) built a gas/smoke fire-prevention system without any remote-notification channel. Tun and Myint (2020) combined smoke and temperature thresholds with GSM alerting but did not report the rationale behind the specific threshold values used or discuss sensor calibration.

Three gaps recur across this body of work: limited or undocumented backup-power provisioning, the frequent absence of a non-latching automatic-reset mechanism, and no consideration of how prepaid airtime constraints affect the GSM notification channel itself. The present design responds to the non-latching reset requirement in its own firmware (Section 3) and targets the third gap directly; it does not attempt to resolve the backup-power question beyond the power-budget estimate reported in Section 5.4.

2.2 Prepaid Service Constraints and USSD Balance Checking

USSD (Unstructured Supplementary Service Data) is a session-based, out-of-band signalling protocol that lets a handset or GSM module exchange short text responses with a network operator's platform without using the SMS or data channel. In Nigeria, the Nigerian Communications Commission directed mobile network operators to harmonise subscriber-facing USSD codes; airtime-balance checking on MTN, Airtel, Glo, and 9mobile now shares the same code, *310#. This harmonisation is what makes a single hard-coded USSD string in this prototype's firmware portable across providers by design, even though only one provider's SIM was used throughout development and testing here.

None of the systems reviewed in Section 2.1 incorporate an automated balance check of this kind: a prepaid SIM in any of those designs could run out of credit and stop sending SMS with no warning to the system's operator. That is the specific gap this work targets, by checking balance automatically and surfacing it in every outgoing alert rather than leaving it invisible until an SMS silently fails to send.

2.3 Tiered Alerting

A binary “alarm or no alarm” scheme, which most of the systems reviewed above implement, sends the same message regardless of whether one sensor or all three have crossed threshold. The design used here instead varies the buzzer pattern, message content, and recipient list according to how many of the three sensors are concurrently triggered, reserving dual-recipient messaging (property owner and fire department) for the case where all three sensors agree. The intent is for a single-sensor reading, more likely to be a nuisance trigger than agreement across all three sensors, to prompt investigation by the property owner alone, while reserving external emergency-service contact for higher-confidence conditions. Whether this arrangement actually reduces false dispatches or notification fatigue in practice was not evaluated in this work; see the limitations discussed in Section 5.5.

III. System Design and Implementation

3.1 Hardware Architecture

The system pairs a SIM900A GSM/GPRS module with an Arduino Uno microcontroller over a serial interface at TTL logic levels (0–5 V). The SIM900A itself requires a 3.2–4.8 V supply and draws current across three distinct operating states: roughly 1.5 mA in its deepest sleep mode (not used operationally in this firmware), approximately 2 mA when idle and registered on the network, and instantaneous peaks of up to 2 A during transmission bursts. A separate 5 V/2 A adapter supplies the module so that these transmission peaks do not pull down the Arduino's own regulator; the peak figure governs power-supply sizing rather than the sustained-current battery-life budget used in Section 5.4, where a measured average of approximately 500 mA during active transmission is used instead. Signal conditioning between the 5 V Arduino output and the SIM900A's 2.8 V logic input uses a passive resistor voltage-divider network, and serial communication runs at 9600 baud. Fig. 1 shows the circuit for the SIM900A integration.

Sensor integration comprises three detection modalities: a KY-026 flame sensor (infrared radiation detection, with an onboard potentiometer for sensitivity calibration), a DS18B20 digital temperature sensor, and an MQ-6 gas sensor (also with an onboard sensitivity potentiometer, and a manufacturer-specified warm-up period of approximately five minutes before stable readings are available). Detection thresholds were fixed in firmware at 45°C for the temperature sensor and an MQ-6 analogue reading corresponding to approximately 500 ppm for the gas sensor. Both values were chosen empirically during development to limit nuisance triggers from ordinary

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temperature fluctuations in Nigerian residential rooms; they were not derived from a formal sensitivity/specificity optimisation, and no external standard is cited for either figure here, since none was independently verified for this manuscript. Calibration of the flame and gas sensors' sensitivity potentiometers was likewise done empirically, the low/medium/high settings characterised in Section 5.2, rather than against a documented calibration curve; a formal calibration procedure with traceable reference sources is listed as future work in Section 5.5.

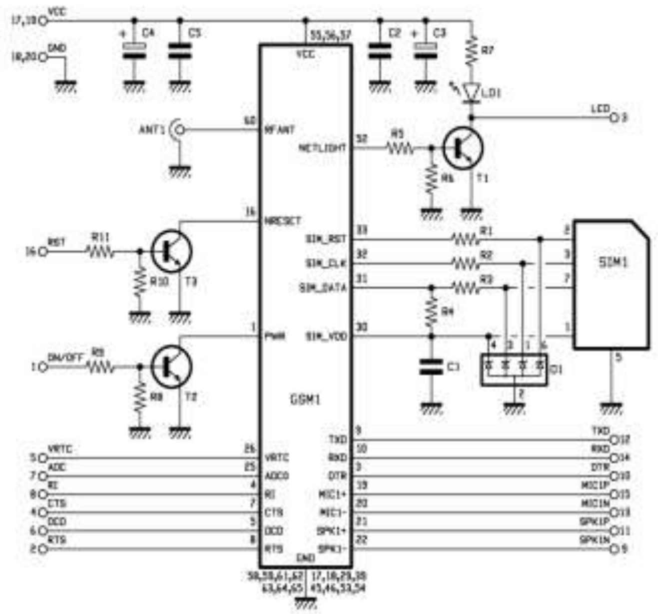

Fig. 1. Circuit diagram for SIM900A module integration with the Arduino Uno microcontroller.

3.2 Communication Protocol Implementation

The system uses the standard AT command interface common to GSM modules. Key commands are AT+CMGF=1 (SMS text mode), AT+CMGS (SMS transmission), AT+CUSD (USSD query), and related registration/initialisation commands issued at start-up. A USSD balance query is sent as AT+CUSD=1,"*310#"; the firmware waits up to 10 seconds for a response containing the +CUSD: prefix, parses the balance value from between the quotation marks in that response, and gives up without retrying if no valid response arrives inside that window, the query is simply attempted again at the next scheduled check. The system does not implement an SMS delivery-confirmation mechanism: what is recorded as an SMS having been "sent" is the module accepting the AT+CMGS command locally, not an end-to-end carrier delivery report, and this manuscript does not claim knowledge of whether alerts were actually received on the recipient handset.

3.3 Tiered Notification Strategy

Table 1 summarises the three alert levels implemented in firmware, based on how many of the three sensors are concurrently above threshold, plus the all-clear condition. A single flat 60-second cooldown between SMS transmissions applies uniformly across all levels, including Level 3; the firmware does not implement a differentiated retry schedule or message-priority queue by alert level. Per-sensor and per-combination boolean flags prevent a repeated notification for a condition that has already been reported, and are cleared only once the relevant sensor reading drops back below threshold.

Level 1 (single-sensor warning) is directed to the property owner only, with a 1-second-on/1-second-off, 800 Hz buzzer pattern. Level 2 (two sensors triggered together) escalates to a 0.5-second-on/0.5-second-off, 1000 Hz pattern, still directed to the owner only. Level 3 (all three sensors triggered together) produces a continuous 1200 Hz tone and dispatches messages to both the property owner and the fire department. Once all readings return below threshold following an alarm, the system sends a single all-clear message to the owner and silences the buzzer.

TABLE 1. Notification escalation levels.

Sensor trigger(s)	Alert level	Buzzer pattern	Recipients	Notification emphasis
Single sensor (flame, gas, or temperature)	Level 1 – Warning	1s on / 1s off @ 800 Hz	Owner only	Investigation recommended
Any two of the three sensors	Level 2 – Urgent	0.5s on / 0.5s off @ 1000 Hz	Owner only	Possible fire developing
All three sensors	Level 3 – Emergency	Continuous @ 1200 Hz	Owner + fire department	Confirmed fire – immediate action
Sensors return to normal after an alarm	All-clear	Silent	Owner only	Confirmation of safety

Message content is data-rich rather than generic: single-sensor warnings name the sensor and current reading where applicable (for example, a temperature warning includes the live °C value), two-sensor messages name both triggered indicators, and the Level 3 message reports flame status, smoke level, and temperature together. Every outgoing message ends with the currently cached SIM balance.

3.4 USSD Balance Monitoring Integration

Balance is checked automatically at two points: once at system start-up, and thereafter whenever more than four hours have elapsed since the last successful check at the moment an SMS is about to be sent, the check is interleaved into the send path rather than run on a fixed independent timer, and continued sensor monitoring is not interrupted while a query is outstanding. The four-hour interval was chosen as a practical balance between catching a depleted balance early and avoiding excessive USSD signalling; it was not derived from a formal cost/risk optimisation. The most recently retrieved balance string is appended to every outgoing SMS, whatever the balance value; the firmware does not withhold or delay an alert while waiting on a balance check, and does not gate transmission on a minimum balance threshold at any alert level, including Level 3. In this respect the system already sends emergency messages without waiting on the USSD check to complete, addressing the sequencing concern that a balance verification step could otherwise delay a Level 3 alert.

IV. Experimental Methodology

Development and bench testing were carried out in Jos, Plateau State, Nigeria, as part of a final-year engineering project rather than as a formally designed experiment: no sample-size planning, randomisation, blinding, or negative-control conditions were used, and a single SIM card on one network provider was used throughout. Three categories of testing were carried out.

First, individual sensor response times were measured using controlled ignition and gas-release sources at fixed distances (10 cm, 50 cm, 100 cm). The flame sensor was tested with a small piece of mattress foam mounted on a stick and ignited at each distance, with five trials per distance timed with a smartphone stopwatch application and averaged. The DS18B20 was tested by bringing a gas-lighter heat source into contact with the sensor from a stable 27°C ambient baseline until the reading crossed 45°C, repeated five times with a one-minute cooling period between trials. The MQ-6 was tested with a gas lighter at 10 cm and a gas-cylinder release at 50 cm and 100 cm, repeated three times per distance because of the sensor's slower response.

Second, the flame and gas sensors' onboard sensitivity potentiometers were characterised at low, medium, and high settings using the same gas-lighter/candle and gas-lighter/cylinder stimuli, at a fixed 50 cm distance, comparing small- versus large-flame and low- versus high-concentration conditions.

Third, a full-system demonstration used three gas lighters simultaneously, one releasing gas near the smoke sensor, one heating the DS18B20 probe, and one held near the flame sensor, to drive all three sensors above threshold together and confirm alarm escalation to Level 3, dual-recipient SMS dispatch with balance appended, and automatic reset once the stimuli were withdrawn.

No independent observers, blinded trials, or uncontrolled/representative fire sources were used in any of the above. SMS and USSD functionality were confirmed to work end to end, including delivery of the illustrative alert messages quoted in Section 3.3, but were not subjected to a structured multi-attempt reliability count with a recorded success rate, and no carrier-side delivery confirmation was implemented or measured. These are treated as limitations rather than omissions to be filled retroactively; Section 5.5 states explicitly what a follow-up study would need to add.

V. Results and Discussion

5.1 Sensor Response Characteristics

Table 2 reports the mean response time recorded at each distance for each sensor, together with the number of repeated trials averaged (5 for the flame and temperature sensors, 3 for the gas sensor, per the methodology in Section 4). Per-trial values were not retained, so no standard deviation, confidence interval, or range is reported; the qualitative observation from testing was that measurements at 10 cm were consistent across repeats for the flame sensor, while measurements at 100 cm, for both flame and gas sensors, showed visibly more trial-to-trial variability.

TABLE 2. Sensor response times at fixed distances, high-sensitivity setting.

Sensor	Distance	Mean response time	n
KY-026 flame	10 cm	0.052 s	5
KY-026 flame	50 cm	0.104 s	5
KY-026 flame	100 cm	≈ 0.156 s	5
DS18B20 temperature	Contact (to 45°C)	0.629 s	5
MQ-6 gas	10 cm	≈ 6.1 s	3
MQ-6 gas	50 cm	≈ 12.2 s	3
MQ-6 gas	100 cm	≈ 17.0 s	3

The flame sensor's rapid response (52–156 ms) makes it the fastest early-warning element in the design; the temperature sensor offers a slower but still sub-second secondary confirmation (629 ms); and the gas sensor, at 6–17 s, is best understood as a confirmatory rather than primary detector given how much later it responds relative to the other two. These figures describe response under the specific controlled stimuli used here (an open ignition source or a direct gas release at short range) and should not be read as detection latency for a developing real fire, whose flame luminosity, radiant heat, and gas concentration profile would differ substantially and unpredictably from a lighter flame or a cylinder release.

5.2 Sensitivity Calibration Results

Table 3 shows how the KY-026 flame sensor's response time varied with its sensitivity potentiometer setting, at a fixed 50 cm distance, for small (lighter-sized) and large (candle-sized) flames.

TABLE 3. KY-026 flame sensor response time by sensitivity setting, 50 cm.

Sensitivity setting	Small flame	Large flame
Low	495 ms	348 ms
Medium	309 ms	205 ms
High	104 ms	52 ms

Table 4 shows the equivalent comparison for the MQ-6 gas sensor, at 50 cm, for low- and high-concentration gas sources.

TABLE 4. MQ-6 gas sensor response time by sensitivity setting, 50 cm.

Sensitivity setting	Low concentration	High concentration
Low	51.8 s	39.0 s
Medium	36.2 s	24.7 s
High	20.5 s	14.8 s

Both sensors respond faster at higher sensitivity settings, roughly a 5-fold speed-up for the flame sensor and a 60% reduction in response time for the gas sensor between low and high settings, but higher sensitivity is also expected to raise the rate of non-fire triggers (bright reflected light for the flame sensor; cooking or aerosol sources for the gas sensor). This

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design used the high-sensitivity setting for the response-time results in Table 2; the trade-off against nuisance triggering was not separately quantified, since doing so would require the negative-control testing discussed in Section 5.5.

5.3 Alert Escalation and Communication Functionality

In the full-system demonstration described in Section 4, driving all three sensors above threshold together produced the expected Level 3 response: a continuous 1200 Hz tone, and SMS messages sent to both the property owner and the fire department with sensor readings and the cached SIM balance included in the message body. Withdrawing the stimuli allowed all three readings to fall back below threshold and triggered the automatic all-clear message and buzzer silence without any manual intervention. Individual single- and dual-sensor conditions were exercised separately during development and produced the corresponding Level 1 and Level 2 buzzer patterns and owner-only messages described in Section 3.3.

This demonstrates that the tiered escalation logic, the USSD balance check, and the non-latching automatic reset function as designed on the bench, for the specific controlled stimuli used. It does not, by itself, establish a detection accuracy, sensitivity, specificity, or false-alarm rate: the trials involved no negative-control conditions (for example, cooking smoke, sunlight on the flame sensor, or ordinary room-temperature drift), no independently observed or uncontrolled fire sources, and no formal count of SMS or USSD attempts against successes. Framing the demonstration in those statistical terms would overstate what was measured; Section 5.5 sets out what a follow-up evaluation would need.

5.4 Power Consumption Analysis

Component-level current draw was measured with a digital multimeter in series with each component's supply line at a stabilised 5 V. The Arduino Uno drew approximately 50 mA in normal operation; the KY-026 flame sensor, approximately 20 mA in its active monitoring state; the DS18B20, approximately 1.5 mA during active temperature conversion (its manufacturer-specified standby current of about 1 μA falls below what the available equipment could resolve and was not independently measured); the MQ-6, approximately 150 mA once its heater element reached thermal equilibrium after warm-up; the SIM900A, approximately 2 mA when idle and registered on the network, and an average of approximately 500 mA during SMS transmission (as distinct from the module's instantaneous 2 A transmission peaks, noted in Section 3.1); and the passive buzzer, approximately 30 mA while sounding.

Summing these figures gives a standby current draw of 223.5 mA (Arduino + flame + temperature + gas sensor + idle SIM900A) and an active-alert draw of 751.5 mA (adding the buzzer and the SIM900A's transmission-average current). The gas sensor's heater dominates the standby budget at roughly two-thirds of the total current.

Dividing a power source's rated capacity by these current figures gives an indicative runtime: about 2.2 hours standby / 0.7 hours active alarm from a 9 V battery (500 mAh); about 9.0 hours standby / 2.7 hours active from four AA batteries (2000 mAh); and about 89.5 hours standby / 26.6 hours active from a 20,000 mAh power bank, roughly three days standby and a little over one day of continuous active alarm. These are first-order calculations from the summed current draw and the manufacturer-rated capacity of each source; no multi-hour or multi-day run-to-depletion test was carried out to confirm them empirically, and none of the runtimes above should be read as a measured result. In particular, a power bank's rated mAh figure describes its internal cell capacity at the cell's own voltage (typically around 3.7 V for a lithium-ion cell), delivered to the 5 V output through a boost converter with its own conversion losses; dividing the rated mAh directly by a 5 V-referenced current draw, as done here, does not account for that conversion loss and will overstate the real runtime by some margin. A power bank is nonetheless expected to outlast disposable-battery options by a wide margin given the current figures above, which is enough to support the system's basic backup-power design goal without requiring a precise runtime figure.

5.5 Discussion and Limitations

The design integrates three elements not found together in the related work reviewed in Section 2: automated USSD balance monitoring appended to every outgoing alert, a non-latching automatic-reset mechanism, and sensor-count-based tiered notification with differentiated recipients. The bench demonstration in Sections 4 and 5.3 shows that these elements work together as designed for the specific controlled stimuli tested. The remainder of this section states plainly what that demonstration does not show, in response to points raised in review of an earlier version of this manuscript.

Detection performance was not evaluated as such. Testing on this project used scripted ignition and gas-release stimuli only, with no negative controls (non-fire heat, smoke, or light sources), no nuisance-source trials, and no independently observed or representative fire tests. Consequently, this manuscript does not claim a detection accuracy, sensitivity, specificity, false-positive rate, or false-negative rate, and any figure of that kind attached to this system in an earlier draft should be disregarded. A credible accuracy claim would require a study built around defined fire and non-fire scenarios, calibrated and independently verified sensor thresholds, a larger and randomised trial set, and reporting of sensitivity, specificity, and confidence intervals, none of which the present dataset supports.

Cross-network compatibility was not empirically tested. The *310# code is harmonised by NCC directive across MTN, Airtel, Glo, and 9mobile, so the design is compatible by regulation; however, only one provider's SIM was used during development, so the module's actual USSD and SMS behaviour on the other three networks is unconfirmed. Testing across all four major Nigerian networks is listed as follow-up work.

Raw data, a formal calibration procedure, and uncertainty estimates were not retained or performed beyond what is reported in Sections 5.1 and 5.2. Per-trial timing values were not logged individually, so the mean figures in Table 2 cannot be supplemented with a standard deviation or confidence interval after the fact; sensor thresholds and potentiometer settings were tuned empirically rather than against a

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documented reference calibration; and message delivery was inferred from the GSM module's local command acknowledgment rather than from an end-to-end carrier delivery report, so no delivery-confirmation success rate is reported. The firmware logic underlying the behaviour described in Sections 3.3 and 3.4 is available from the author on request rather than reproduced in full here.

Power figures are calculated, not empirically validated. As noted in Section 5.4, the reported standby and active-alarm runtimes come from dividing rated battery/power-bank capacity by measured current draw, without a run-to-depletion test and without accounting for power-bank boost-converter losses; real-world runtime, particularly from the power bank, should be expected to fall somewhat short of the figures given.

Retry and prioritisation behaviour is simpler than a tiered scheme might suggest. A single 60-second cooldown governs every SMS transmission at every alert level, including Level 3; the firmware does not implement differentiated retry counts, retry intervals, or a message-priority queue by alert level, and no claim to that effect should be attached to this system.

Beyond these points, the study's scope was limited to a single indoor residential-type location and a small number of bench trials per condition, which limits how far any of the qualitative findings above generalise; component cost was not tracked and is not reported; and testing was confined to controlled ignition sources rather than industrial or commercial fire scenarios. Addressing the review points above, negative-control and randomised-trial testing, multi-network validation, a documented calibration procedure with retained raw data, and an empirical power-runtime test, would require a follow-up data-collection effort beyond what this manuscript's underlying dataset supports, and is left as the paper's primary direction for future work rather than claimed here.

VI. Conclusion

This work developed and bench-tested a prototype fire-detection communication architecture that integrates automated USSD-based SIM balance monitoring with a tiered, sensor-count-based emergency notification scheme, on a SIM900A/Arduino Uno platform combining flame, temperature, and gas sensing. The demonstration showed the intended behaviour on the bench: escalating alert levels with distinct buzzer patterns and recipient lists, balance information appended to every outgoing SMS, dual-recipient dispatch on confirmed triple-sensor activation, and automatic non-latching reset once conditions normalised, alongside a first-order power budget consistent with multi-day standby operation from a power bank.

These results support the system as a working, low-cost proof of concept and identify a design gap, prepaid-airtime awareness integrated directly into a fire-alert pipeline, that is not addressed in the related work surveyed in Section 2. They do not establish detection accuracy, false-alarm performance, cross-network reliability, or empirically validated battery runtime, each of which was explicitly out of scope for the testing carried out and is identified in Section 5.5 as necessary follow-up work: a study with defined fire and non-fire scenarios and negative controls, randomised and larger trial sets, testing across all four major Nigerian network operators, a documented sensor-calibration procedure with retained raw data, and an empirical battery run-to-depletion test.

Future work beyond addressing those gaps could reasonably include predictive balance-depletion modelling from historical usage, an alternative notification pathway (a voice call or a companion mobile-app push notification) as a fallback when SMS balance runs critically low, and evaluation of the same design pattern in other prepaid-dominated telecommunications markets.

References

[1]. Al Hasani, I. M. M., Kazmi, S. I. A., Shah, R. A., Hasan, R., & Hussain, S. (2022). IoT-based fire alerting smart system. Sir Syed University Research Journal of Engineering & Technology, 12(2), 46–53. https://doi.org/10.33317/ssurj.410

[2]. Al Shereiqi, I. M., & Sohail, M. M. (2020). Smart fire alarm system using IoT. Journal of Student Research, 9(2). https://doi.org/10.47611/jsr.vi.882

[3]. Alqourabah, H., Muneer, A., & Fati, S. M. (2021). A smart fire detection system using IoT technology with automatic water sprinkler. International Journal of Electrical and Computer Engineering, 11(4), 2994–3002. https://doi.org/10.11591/ijece.v11i4.pp2994-3002

[4]. Baba, M. C., Grado, J. L., Solis, D. J. L., Roma, I. M., & Dellosa, J. T. (2022). A multisensory Arduino-based fire detection and alarm system using GSM communications and RF module with an Android application for fire monitoring. International Journal of Innovative Science and Research Technology, 7(3), 964–972.

[5]. Edozie, E., Eze, V. H. U., Jimmy, O., Janat, W., & Ugwu, C. N. (2023). Design and implementation of fire prevention and control system using ATmega328P microcontroller. International Journal of Innovative and Applied Research.

[6]. Hery, H., Haryani, C. A., Mitra, A. R., & Widjaja, A. E. (2022). The design of microcontroller based early warning fire detection system for home monitoring. International Journal of New Media Technology, 9(1), 6–12. https://doi.org/10.31937/ijnmt.v9i1.2405

[7]. Tun, M. Z., & Myint, H. (2020). Arduino-based fire detection and alarm system using smoke sensor. International Journal of Advances in Scientific Research and Engineering, 6(4), 89–97. https://doi.org/10.31695/IJASRE.2020.33792

[8]. Umaru, K., & Tartisious, D. J. F. (2023). Design and implementation of a fire detection, alarm and suppression system using programmable logic controller (PLC). International Journal of Academic Engineering Research, 7(12), 20–29.

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