Fuzzy-Estimation Control for Improvement Microwave Connection for Iraq Electrical Grid

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Abstract. The demand for broadband wireless services is increasing day by day (as internet or radio broadcast and TV etc.) for this reason and optimal exploiting for this bandwidth may be other reasons indeed be there is problem in the communication channels, it’s necessary that exploiting the good part form this bandwidth. In this paper, we propose to use estimation technique for estimate channel availability in that moment and next one to know the error in the bandwidth channel for controlling the possibility data transferring through the channel. The proposed estimation based on the combination of the least Minimum square (LMS), Standard Kalman filter, and Modified Kalman filter. The error estimation in channel use as control parameter in fuzzy rules to adjusted the rate and size sending data through the network channel, and rearrangement the priorities of the buffered data (workstation control parameters, Texts, phone call, images, and camera video) for the worst cases of error in channel. The propose system is designed to management data communications through the channels connect among the Iraqi electrical grid stations. The proposed results show that the modified Kalman filter have a best result in time and noise estimation (0.1109 for 5% noise estimation to 0.3211 for 90% noise estimation) and the packets loss rate is reduced with ratio from (35% to 385%).Keyword: error estimate channel, least square, minimum mean square error , fuzzy logic .

1.Introduction
Electricity is one important issues in the word and especially in Iraq it comes second after the security after 2003. The power grid contains: [1]
1- energy production (power station) as a thermal’s power station, gas turbine combined cycle power’s station and hydro power’s station.
2- Transmission: the networks transmission of Iraq be composed of (400kV,132kV) system. Generations was connecting to the132kV or to 400kV systems. The transmission’s system of the 400kV especially composed of single’s circuit overhead lines’ capacity of around 1,000 MVA. This system represents as a power transmitting of highway from the southern regions and northern regions to the centric regions. The networks of 132kV was the sub transmission network that delivered the power to the distribution’s networks inside the governorates and also representing the connection between governorates.
3- Distribution’ system consists of many substations such as (33/11kV,11/0.4 kV) and overhead lines (33kV, 11kV,0.4 kV) and underground’s cables. [1] The power grid stations contains has (as shown in Fig.1) a national control center linked RTUs, and renewing the PLC and Microwave communication’s systems (400kV,132kV) transmission’s systems. [1]
As being one of the most important factors to support development, the amount of electrical power demand increased rapidly. During the last six years[3] and There is an increase in
demand for electric energy that mean we need to add an new units in the power station, transmission and Distribution system. [2, 4]

One part of the infrastructure in the power grid in Iraq is a control and communication. Control means work in the same unit as a (micro SCADA) but communication means transfer data or information between units according to the direction of linking these substations in the power grid. In this thesis we will focus in communications of transmission (substation 400k.v, 132k.v).

![Electricity system in Iraq](source: GAO, 2007)

Figure 1. Illustrates the power station, Transmission and Distribution system [2]

More applications of distributing multimedia were became an integrated with computing and communication’s environments. For achieving this goal, multimedia applications should be delivering high QoS. This is represented a challenges when distributed multimedia applications were executed on general purposes operating’s systems and network that was developing to process best-efforts data and transmission, therefore, they bear high level of troubles in resource allocation when treating continuous media. For solving this challenge, many techniques for QoS adaptations for distributing multimedia system situation are proposed.[10]

The network problem congestions controls stay as critical high priority and issues, principally when increase the demands in using the Internet during delay-time sensitives application with different Qualities of Services (QoSs) requirements’. [7]

Many researches effort a large numbers of difference proposed controls systems. But still no universal acceptable congestions controls solution. Even with techniques of the classical-controls systems proposed in different researches, still don’t perform sufficient controlling of the dynamic, and the non-linearities network or in Internet. [7]

For many years, fuzzy logic control is well known Computation Intelligences techniques in the best applications are used in many control researches especially in the networks and communication. [7]

In this section, we explain and discuss some of the control system used the estimation operation in controlling the network QoS, and the researches used in their suggestion the fuzzy control system techniques:

M. Reda and et al (2006) [1], they review the Iraqi-electrical-power systems history and illustrate the methods to enhancement and improved the infrastructures. The electrical-network due to the military operations, substantial damages, and poor maintenances with a very little developments and assessment replacements, that all results in reduction qualities operations and communications. They proposed some solution in the ongoing repairing infrastructure of the grid and stations and connect them with intelligent modern communication system of the Iraqi electricity grid.

Ghulam Abbas and et al (2008) [11], they propose a novel-framework, depend on states-Estimation, for the Networks Management-System approaches to controlling the network
traffics flow, routings, hard-ware malfunction, congestions and resources managing in data transfer network. The aim is to eliminate anomalies events and other dis-crepancies between network models that leads to bad operation in network and restrict the performance and threatens the security and integrity of the network. The proposes framework was validate using cases studies that focus on the congestion-control and have demonstrate favourable result in term of enhancing data deliveries with few packets losses and re-transmissions. The simulation results also suggest that States Estimations basedon congestion-control technique offer system monitoring improving with enhancement control network security.

Yasser Sadri and Sohrab Khanmohammadi(2013) [12], they introduced a QoS-Aware Scheduling technique depend on fuzzy-logic, for traffics managing in WiMAX point to multi point (PMP) network. The proposes technique was attempt to guarantees delays and throughputs QoS requirements. Its consider QoS requirements and radio-quality of users in decision-making processing. A simulation experiment series have achieving to evaluated the proposes scheduling-system performance. Getting the (QoS) for different multi-media service are an important issues in IEEE-802.16 (Wi-MAX) network. A scheduling techniques which satisfy the QoS criteria have become important for multi-media network. Also, scheduling-algorithms for wireless network were high complex than that of the wired network due to quality variation of channel and radio-resource limitation. The simulation results illustrate that the proposes technique perform more effective to achieving the QoS requiremets and increase different types traffic performance.

Mehrdad Taki and etal (2016) [13], propose joint’s scheduling and link’s adaptation techniques was designed by fuzzy-logic. the scheduler was designing for providing difference requirements for throughput and allocating the users shared media in optimal way Depending on their important.coding, transmit power and Adaptive modulation are using an average powers restrictions based on every power supply of the user. Differen bit-error-rate and QoS-delays restrictions were providing to all links. Numerical’s evaluation displayed that the proposed schema that based on fuzzy has the execution extremely closing to the analytic approaches, basically minimum complexity.

Abbas Ali Rezaee and Faezeh Pasandideh(2017)[14, when the patient’s body sensors are constantly send the data packets, probably congestions may be happened. This was increasing the loss of packet ratio and hence the efficiency was decreasing and it will be affecting on system overall performance, so the congestion’s control is a main challenges. Detecting the Congestions and control it was fundamental for some systems.active queue methods’ management was proposed here for determining the packet’s losing probability. AQM was integrating the early random detections and Fuzzy PID (fuzzy-proportional-integral-derivative) controlling methods jointly. When PID was joined with the fuzzy logic, that was helping to controlling the target buffer’s queue. The controller of the fuzzy logic was estimating and adjusting the rates of sending of every node. By using MATLAB and OPNET simulators, the researcher was comparing proposing protocol with Priority-based-Congestion-Control-protocol data-loss-rate.

In this paper we suggest the fuzzy rules control with many channel error (noise) estimations to control the data transferring in the Microwave channels connected the power stations in the Iraqi electrical grid.

2. Channel Estimation Techniques
Many methods for Channel estimation problems based in semi-blind approach are used Least Mean Square(LMS) Algorithms
Estimation algorithm of LMS uses the gradient vector for estimation of the main data. Iterative procedures combined with the LMS method made successful rectifications to the weight vectors in the negative direction of the gradient vectors which results minimum MSE(mean-square-error). In comparing of other algorithms, the LMS algorithm was comparatively easy:
From the method of steepest descent, weight vector equation is given by:

\[ w(n) = w(n) + \frac{1}{2} \mu \left[ -\nabla \mathbb{E}\{ e^2(n) \} \right] \]  

(1)

Where \( \mu \) is the step-size factor that controls the characteristics of convergence of the LMS algorithm.

**Kalman filters Estimator [24, 25]**

The Kalman filters are founded by linearly dynamical system discretized in times domain. These filters were constituted by a Marko’s chains structured by linear factors anxious about the error that include the Gaussian’s noises. The system status was represented as a real number vectors. In each increment of discrete time the system was applying linear operators to the state for generating a state was discovered recently that has some data from controls and some noise that mixed with on the system. After that other linearly operator’s that mixing with more noises was generating the supervised outputs from the correct state (hidden stat). Kalman’s filters may be considered as analogous to Markov’s hidden model with different key that the variables of hidden states value in a continuous space (against the Markov hidden model, it’s state in discrete space).

For using Kalman’s filter for estimating the internal state of an operation, that only sequence of noisy considerations was given a, first should model the operation in conformity of the Kalman’s filter framework.

1. **Equation of Process**

\[ X_k = A_{k-1} + W_{k-1} \]  

(2)

Where:

- \( X_k \) = the state time k to time k-1, \( A \) = transition matrix, \( W_{k-1} = N \) noise of Gaussian process.

2. **Equation of Measurement**

\[ Z_k = H_{k} + v_k \]  

(3)

Where:

- \( H \) = measurement matrix, \( Z_k \) = observed measured at time k to k, \( v_k = N \) noise of Gaussian measurement.

3. **Time Update Equation**

\[ \hat{x}_k = A\hat{x}_{k-1} + w_k \]  

(4)

Where:

- \( \hat{x}_k \) = A prior estimate of state(s), \( \hat{x}_k \) = covariance error estimate for the next step of time k, 
- \( A \) = transition matrix, \( W_k = N \) noise of Gaussian process.

4. **Update Measurement Equations**

\[ K_k = P_{k|k} (H^T P_{k|k} H^T + R)^{-1} \]  

(5)

Where:

- \( K_k \) = is the Kalman growth (gain), \( P_k \) = a posterior error estimate

3. **The Proposed System**

Many distributed multi-media were become an integral parts of the network environment. In order to get this target, the multimedia files should deliver with highest Quality of Services (QoS). The challenges in the multimedia distribution are networks errors and noise in the data...
traffic, also data transmission mechanism between power station of the electrical grid. In the power grid in Iraq, either PLC (power line carrier) used to send data over the lines power phase and the multiplexer (MUX with pilot cable, microwave, fiber optic) also used to send data separately from the transmission power lines with some problems in the network QoS.

The main goal of the proposed system is to improve the data transfer in the wireless network connected the power stations in the Iraqi Electrical Grid. The improvement operation can be done by using the intelligent technique to solve many problems described above by optimization data transfer over the electricity grid. The selection of the Microwave channel due to the limitation of PLC (power line carrier), and because the grid power have many substation uses Microwave network with 2Mbps bit rate behind the old (PLC) that has limited capacity channel (64 kbps).

In this research, we proposed the Fuzzy Logic control rules used for adaptive the Microwave network QoS in order to distributed multi-media (like data parameters, speech phone calls, images, and webcam videos) and control the transmission in the Iraq power grid to improvement the data transmission operation. This goal can be done through calculate the error rate (caused by noises) and estimate the next error rate in the network channel. Depending on the error rates, the best fuzzy rules can apply to take adjust the compression techniques with compression ratio and the number of the multimedia can be send as subchannels transfer (and number of delayed multimedia stored in delayed buffers).

In this proposed system, the error estimation stage checks the current error rate (like noise ratio) and estimate the error rate in the next period by using four different techniques (Modified Kalman Filter MKF, and LMS) by using the automatic packet generation technique to generated and send testing packets to all active nodes in the network. Estimation vector will be used in the proposed Fuzzy controls communication stage. Many compression techniques were used like (Lossless and lossy) JPEG image compression, Pulse Code Modulation PCM (with different quantization bit levels) for speech compression, and H.264/AVC for web camera videos. There are different compression and qualities degree are used depending on the decision of the proposed Fuzzy control stage. The proposed system was designed to be fast in the implementation by use the modern algorithms and reduction these algorithms as possible. Figure 2 shows the flowchart of the proposed system.

The proposed system can divide into four stages:

**Network stage:** in this stage the network parameters, nodes number, sending and receiving test packets are illustrated.

**Error Estimator Stage:** the error calculated and estimated for the next time periods using the modified Kalman filter, Kalman filter, and LMS estimators.

**Fuzzy Control Stage:** The outputs of the estimators are input to the Fuzzy rule control to adjusted the priorities and compression ratio and types.

**Send Media Stage:** in this stage, the media sending after applying the fuzzy control rules on the buffered media like speech, web camera video, images, and controlling power station parameters through the subchannels. The sending operation is based on the TCP/IP protocol.

### 3.1 Proposed Modified Kalman Filter

The first modification is to the Kalman filter in order to make this filter more effective for estimation the error rate, the modification by adding the previous mean noise ratio and the previous covariance of the observation noise at a time.

MKF is not only effective practically but attractive theoretically as well accurately, the optimal states are found with smallest's possible factual errors, recursively. However, there are four phases for describe MKF mathematically as follows:

**1. Proposed Modified Equation of process**

\[ X_k = A \times X_{k-1} + (W_{k-1} + MPNR)/2 \]  

**Where:**

- \( X_k \) = the state time \( k \) to time \( k-1 \).
- \( A \) = transition matrix.
- \( W_{k-1} \) = noise of Gaussian process.
- \( MPNR \) = The mean of previous noise ratio during the total last time period.
2. Proposed Modified Equation of measurement

Figure 2. The Flowchart of the proposed system.
\[ Z_k = H \hat{x}_k + (v_k + MPNR)/2 \]  
\textbf{Where:}  
- \(H\) = measurement matrix.  
- \(Z_k\) = observed measured at time k-1 to k.  
- \(v_k\) = noise of Gaussian measurement.  

3. Proposed Modified Time Update Equation  
\[ \hat{x}_k = \hat{x}_{k-1} + (2 * W_k + MPNR)/3 \]  
\textbf{Where:}  
- \(\hat{x}_k\) = A priori estimate of state.  
- \(\hat{x}_{k-1}\) = covariance error estimate for the next time step k.  
- \(A\) = transition matrix.  
- \(W_k\) = noise of Gaussian process.  

4. Proposed Modified Equations of measurement update  
\[ K_k = P_k H^T (H P_k H^T + (2 R_k + R_{k-1})/3)^{-1} \]  
\textbf{Where:}  
- \(K_k\) = is the Kalman growth (gain).  
- \(P_k\) = a posterior error estimate.  
- \(R\) = the covariance of the observation noise at a time.  

The mechanism of MKF Algorithm clarified as shown in 'figure (3)'. In order to understand the common MKF better. There are three main calculating according to the four main equations that need to be done frequently. **First** one in calculating the Modified Kalman Gain (MKG) to make the estimate zooming into the actual correct value, so we need to calculate each time this MKG. Then its need to calculate the current estimate each time are going to update the estimate. Finally, it is important to re-calculate the new error (the uncertainty) in the estimate. From the figure, it is clear that it is need two things know for calculate the MKG, first one is the error in the estimation (the mean previous error or the original error), and later is the error in the data input, both of these feed into the calculation come up. Secondly, the MKG feeds into the calculation of the current estimate depending upon what the gain is the adjustment to the mean previous estimate that come up with a new estimate of the gain, beside of the gain it is depending upon the mean and previous estimate and with the next iteration the new data comes in. Then it has been used to re-calculate the new estimate, so that it is always feedback in on itself that mean it is need the mean previous estimated that calculated before but if it is the first time it need to take the original estimate. Finally, when the calculation in one and two has been done, then calculation for the error estimation can be achieved for the next time around.
The Fuzzy Control Stage

Fuzzy Control Stage contain the main operation of the controlling the sequence of the transfer media. The outputs of the error estimation stage is a Error Estimation Ratios (EER) Vector passed as input to the Fuzzy rule control stage to adjusted the priorities, compression ratio, compression types, and Sequence of the media. Also the Mean Perivious Noise Ratios (MPNR) will compute from the pervious noise or error estimated for the channel during the work duration.

The average of EER vector (without Mean Perivious Noise Ratios MPNR) will used as the final error estimation value called Mean Final Error ratio (MFER) and compare it with the MPNR, if the MPNR greater than with high difference, then MFER as estimate ratio, if the MPNR close or near the MFER then MFER = (MFER + MPNR)/2. From this ratio, the proposed system selects the appropriate fuzzy rule to control the sending operation.

The proposed Fuzzy rules are as following (where no. of media in buffers (MB), Initial no. of subchannels (IM), and Compression ratio CR):

Rule 0: if the MPNR greater than with high difference, then MFER as estimate ratio, if the MPNR close or near the MFER then MFER = (MFER + MPNR)/2.

Rule 1: If (MFER ≤5% of the channel capacity) and (MB ≤IM) then: No compression, CR = 0, no change the priority and sequence of media in transmission buffers, no delay.

Rule 2: If (5% < MFER ≤15% from the channel capacity) and (MB ≤IM) then: Lossless compression, CR = 15%, no change the priority and sequence of media in transmission buffers.

Rule 3: If (5% < MFER ≤15% from the channel capacity) and (MB > IM) then: Lossless compression, CR = 15%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, images, and the less priority videos), no delay needed in videos subchannels.

Rule 4: If (15% < MFER ≤25%) from the channel capacity) and (MB ≤IM) then: Lossy compression, CR = 15%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, images, and the less priority videos), and need to delay in last two videos subchannel.

Rule 5: If (15% < MFER ≤25%) from the channel capacity) and (MB > IM) then: Lossy compression, CR = 25%, change the priority and sequence of media in transmission (speech, Parameters, control data, images, and the less priority videos), and need to delay in last three videos subchannel.

Rule 6: If (25% < MFER ≤35%) from the channel capacity) and (MB ≤IM) then: Lossy compression, CR = 40%, change the priority and sequence of media in transmission...
buffers (speech, Parameters, control data, images, and the less priority videos), and need to delay in last three videos subchannel.

Rule 7: If (%25<MFER≤35% from the channel capacity) and (MB>IM) then: Lossy compression, CR=50%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, images, and the less priority videos), and need to delay in last five videos subchannel.

Rule 8: If (%35<MFER≤45% from the channel capacity) and (MB≤IM) then: Lossy compression, CR=50%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, images, and the less priority videos), and need to delay in last four videos subchannel.

Rule 9: If (%35<MFER≤45% from the channel capacity) and (MB>IM) then: Lossy compression, CR=60%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, images, and the less priority videos), and need to delay in last six videos subchannel.

Rule 10: If (%45<MFER≤60% from the channel capacity) and (MB≤IM) then: Lossy compression, CR=70%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, images, and the less priority videos), and need to delay in last seven videos subchannel.

Rule 11: If (%45<MFER≤60% from the channel capacity) and (MB>IM) then: Lossy compression, CR=75%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, and no images and videos), and need to delay in last eight speech subchannel.

Rule 12: If (%60<MFER≤65% from the channel capacity) and (MB>IM) then: Lossy compression, CR=75%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, and no images and videos), and need to delay in last seven speech subchannel.

Rule 13: If (%60<MFER≤65% from the channel capacity) and (MB>IM) then: Lossy compression, CR=75%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, and no images and videos), and need to delay in last eight speech subchannel.

Rule 14: If (%65<MFER≤85% from the channel capacity) and (MB>IM) then: Lossy compression, CR=75%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, and no images and videos), and need to delay in last seven speech subchannel.

Rule 15: If (%65<MFER≤85% of the channel capacity) and (MB>IM) then: Lossy compression, CR=75%, change the priority and sequence of media in transmission buffers (speech, Parameters, control data, and no images and videos), and need to delay in last eight speech subchannel.

Rule 16: If (MFER>85% of the channel capacity) then the channel very noisy and no valid to transfer data.

Rule 17: The comparison error rate used in the rules (1-16) can be change depend on the other parameters (like the Air temperature, Rain, Light day and night, station location (Urban areas), and frequencies of the main channel). This update rules.

As shown above, the fuzzy rules proposed to use in this stage covered the noise ratio from the 5% to 85%, and choose the rule and their actions depend on these MFER. The priority is very important to make the re-sequence the media in the transfer buffer more effective in sending the important data than others. The compression type and ratio help in avoid the noises interference by reduced the size of data with keeping the most details as possible. The reduction of data transfer in the channel useful in reduction the noise infection and sending time. The error ratio (noise) can be change during year and locations of the power stations.

4. Results and Discussion
The results from the implementation proposed system in the simulation environments were show the improvement in the increasing number of sending media (subchannels) by at least 3 times, and reduction (with 30-90%) in the losing packet through connection operation for all different
error ratios. Time of the all operations in the proposed system was acceptable and can be considered fast with average (1-3) second. Also, the modified Kalman Filter estimator has best results of error estimation from the other used estimators. Also, the modified Kalman filter are more speed from it (with superior from th LMS ). Figures (4-7) show the results of the proposed syste. Also, the tables (1-2) shows the results of the estimation stage.

**Figure 4.** The Results of the Sending-Receiving Test Packets

![Figure 4](image)

**Figure 5.** The Modified Kalman and Standard Kalman Filter Results

This figure shows the results of error estimation by modified Kalman filter (red line) for different types of noise through the time is near to the actual error rate, while the Standard Kalman filter (SKF) (yellow line) has some different from the actual error rate measured.

**Table 1.** MKF and SKF estimator results

| Actual noise ratio | MKF estimation | Time (MKF) sec | SKF estimation | Time (SKF) sec | LMS estimation | Time (LMS) sec |
|--------------------|----------------|----------------|----------------|----------------|----------------|----------------|
| 5%                 | 5.011%         | 0.1109         | 5.123%         | 0.1613         | 6.234%         | 0.2390         |
| 10%                | 10.041%        | 0.2178         | 11.511%        | 0.1655         | 12.526%        | 0.2598         |
| 15%                | 15.102%        | 0.1341         | 17.774%        | 0.1660         | 17.390%        | 0.2786         |
| 25%                | 25.109%        | 0.1398         | 27.451%        | 0.1742         | 28.451%        | 0.2999         |
| 35%                | 35.197%        | 0.2109         | 37.799%        | 0.2134         | 38.563%        | 0.3213         |
| 45%                | 45.412%        | 0.2231         | 48.123%        | 0.2309         | 48.382%        | 0.3214         |
| 60%                | 61.345%        | 0.2786         | 63.569%        | 0.2817         | 64.512%        | 0.3322         |
| 65%                | 66.209%        | 0.2823         | 67.820%        | 0.2956         | 67.425%        | 0.3390         |
| 75%                | 76.561%        | 0.2851         | 78.123%        | 0.3017         | 79.123%        | 0.3403         |
| 85%                | 86.341%        | 0.3109         | 88.407%        | 0.3280         | 88.567%        | 0.3439         |
| 90%                | 91.890%        | 0.3211         | 93.980%        | 0.3301         | 94.326%        | 0.3560         |
As shown in the table (1), the MFK is more accuracy from the SKF and LMS estimator in all ratio of noise. But the time of the SKF is less than operation time in a few msec.

As shown in figure 7, the packets loss rate is reduced with ratio from (35% to 385%) after using the proposed system.

5. Conclusions
In this research, the error estimation filters were used to checks the current error rate in channel communication for the Iraqi Electrical Grids (likes noise ratio) and to estimates the error rate
for the next periods by using the combination of the three different techniques (MKF, SKF, LMS) for the Microwave channel.

Fuzzy rules are used to select the transformation conditions and parameters for the current environment and estimations noise rates. As shown from the above results, the error/noise estimation output level will improve and adjusts the data transfer in the noisy channel by help in selection the no. of subchannels, compression ratio, compression type, and the specific delay transfer time for the lowest priority media subchannels passed to the Microwave channel of Iraqi Electrical Grid. The proposed system implements in the simulation environment to test its operation and techniques and get the packet loss rate with (35% to 385%) depends on the noise ratio levels.

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